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ANNOTATED BIBLIOGRAPHY OF ECONOMIC LITERATURE ON WETLANDS

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by

Aaron J. Douglas
U.S. Fish and Wildlife Service
National Ecology Research Center
2627 Redwing Road
Fort Collins, CO 80526-2899

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

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PREFACE

This report attempts to help natural resource economists, wetlands scientists, resource managers, government officials, and sportsmen better understand controversies surrounding wetlands allocations by surveying some of the recent economic literature on wetlands. It deals almost exclusively with academic literature, though some of the best work cited is policy or management oriented. This report is, in fact, a particular kind of survey paper--an annotated bibliography of the recent (post-1965) economic literature on wetlands--but it has a good deal in common with survey papers that attempt to weigh, assess, and evaluate the ensemble of contributions that have occurred in any fast developing field of social research. An effort has been made to list the relevant literature in this report, and to interpret, analyze, and evaluate this literature in accompanying commentaries.

Some of the recent economic literature on wetlands attempts to impute values to wetland functions and preservations benefits with the conventional analytic tools of contemporary economic analysis. Numerous difficulties have been encountered in developing methodologies for estimating wetlands preservation benefits because of the low marginal values and large total values of the resource and its various outputs and functions. Principal among these difficulties is the use of the term "value"; economists use the term to denote a quantitative economic yardstick for making objective comparisons of various resource allocations.

The sharply divergent meanings that the term value has for various other members of the wetlands scientific community is taken as a fact of life rather than as a starting point for discourse in the present study. Some wetlands scientists clearly refer to value as the intrinsic esteem that society would place on wetlands if society were both properly informed about the myriad useful ecological, biological, and hydrological functions performed by these landscape forms and (if society) used the correct set of ethical norms to value nonmarket resources. Thus it is appropriate to warn the uninitiated that the rich diversity of wetlands functions has a counterpart in the bewildering variety of approaches to the economic analysis of the social values imputed to these functions.

Some wetlands scientists regard conventional economic analysis as a veil that keeps society from acknowledging the obvious value of the panoply of wetlands functions. Conventional economic analysis can attempt to measure nonmarket value, but only within the context of a value system that--from the economist's perspective--attaches implausibly high values to tickets to athletic events, Beatles memorabilia, and Rolls Royce automobiles. The economic analyses of certain of these scientists fall within certain familiar patterns (single commodity theories of value) that are rejected out of hand by most Western social

scientists as inflexible and simplistic. These scientists propose to measure the value of wetlands by the dollar value of the fossil fuel equivalent of the solar energy that the wetland converts to plant biomass. This is clearly not a statement about observable human economic activities, nor does it purport to be a statement about hypothetical human behavior under certain interesting, relevant circumstances. Thus when certain wetlands scientists talk about value, they use the term in a remarkably different fashion from that employed by economists and social scientists, who use the term to refer to individual and societal choices in the context of a universe with a great diversity of commodities but limited private and social resources.

One broad generic theme that is readily recognized in all of the literature discussed here is the distinction between total and marginal values. Many works discussed in this bibliography cope with the inherent diversity of the subject by focusing on one type of wetlands and imputing values to a broad panoply of functions for this class of wetlands. However, one type of function often dominates other socially useful outputs for any given class of wetlands. For the prairie potholes, say, this dominant function is probably breeding and summer habitat provision for migratory waterfowl. And in the prairie pothole region, the principal cause of wetlands loss is farmland drainage and conversion. Thus within this diversity a number of readily recognized social and biological themes emerge to orient the wetlands specialist as well as the general field biologist.

To their credit, economists doing research in imputing values to wetlands have often recognized the complex nature of wetlands and have shaped their research activities to incorporate the geological, hydrological, and biological diversity of these land forms. This partly accounts for the fact that one of the apparent gaps in the literature is the absence of generic theories of wetlands values that encompass a wide range of wetlands types.

Some of the major wetlands types include glaciated prairie potholes, bottomland hardwood swamps, coastal salt marshes, coastal estuarine zones, playa lakes, and riparian zones of the arid western U.S. Not all wetlands perform all of the functions that ecologists, economists, and environmentalists allege to be beneficial to man. Among these functions are the provision of fish and wildlife habitat, geochemical cycling, sediment trapping, contaminant removal, flood prevention, erosion control, climatological stabilization, groundwater recharge and storage, habitat for endangered and rare flora and fauna, recreation and aesthetic benefits, and opportunities for scientific research. In addition, there are certain commercial economic activities that are heavily contingent on wetlands preservation, including timber and shellfish harvesting.

Not only is the distribution of these functions and values among various wetland types quite irregular, there is too little recognition among economists and the environmentally minded public that certain functions clash with others. For example, selective or clearcutting of timber stands may yield a modest positive pecuniary return. It can also, in certain situations, limit the spread of infectious diseases. However, diseased stands might provide wildlife habitat of the same or better quality as healthy stands, while clearcutting involves the loss of valuable wildlife habitat and important aesthetic amenity values. Thus the provision of some outputs by selection of management decision variables

implies a reduction in certain others. Some of the outputs and activities are substitutes for each other, while others are complements.

Two earlier bibliographies on this subject have been written, one by Leitch and Scott (1977) and one by Leitch with various collaborators (1981). Moreover, Leitch and Eckstrom (1989) have recently written a book-length annotated bibliography of wetlands literature. The Leitch-Eckstrom work includes sections on wetlands regulation and wetlands management as well as a lengthy section on wetlands economics literature. Their book is the last work cited in this monograph. The other two annotated bibliographies co-authored by Leitch feature wetlands literature on subjects other than economic valuation. Despite the fact that the subject of wetlands literature is so large as to be somewhat unwieldy, these two early reference articles are easy to use because they are divided into a number of parts focusing on specific subjects.

The current annotated bibliography features an extensive discussion of the research techniques that have been developed by economists to assess a wide range of public amenity values, including wetlands preservation benefits. Also, the current monograph generally discusses important contributions in more detail than do the three antecedent works on this subject. The most important gap in the social science literature on wetlands is the absence of adequate discussion of the failure to translate the social values embodied in the economics literature into effective legislative action to stem the loss of wetlands caused by various developmental pressures. Some scientists seem to believe that the critical step in the development of adequate regulatory and legislative safeguards for halting wetlands loss is the demonstration that per acre dollar values for aggregate wetland benefits are very large (Gosselink et al. 1974). I believe that recent wetland losses are generated primarily by the interrelated problems of public education about wetland resources, legislative inertia, and the absence of multi-agency regulatory activity directed towards wetlands preservation.

The following bibliographic databases (covering the period from 1976 to the present) were searched for scholarly articles dealing with the economic benefits of wetlands preservations: (1) Agricola, (2) Dissertation Abstracts Online, and (3) Environline.

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INTRODUCTION

This bibliography is intended for the use of wetlands scientists, policy analysts, and natural resource professionals who have little acquaintance with natural resource economics, and natural resource professionals who have some background in economic analysis and wish to sharpen their appreciation of the specialized methods used to value the nonmarket uses of wetland resources. It is not intended to serve as a first primer on natural resource economics. The purpose of including this discussion is to introduce the reader to the fact that specialized language and analytic techniques are used in this field, and that summary discussions of these techniques are not available in introductory or intermediate level economics textbooks.

A key difficulty in economic analysis lies in the need that economists have to express common-sense terms such as "demand" or "supply" in a precise way; this facilitates the interpretation of data and is a powerful aid in making internally consistent, policy analysis. Natural resource economists would like to find a consistent, intuitively plausible measure of the social benefits conferred by some good or service. The most common fallacy noneconomists make in this field is to use expenditures as a measure of well-being or benefits. This measure is defective; expenditures may rise, while benefits fall. The following simple example should clarify the issue. Suppose that a certain population center, in the 1940's, is located 5 miles from a riverine recreation site. Suppose that a factory opens up 15 miles away from the site during the 1950's, and closes at the end of the 1960's; and that during this 20-year period, the bulk of this region's populace resides 15 miles from the site, close to the factory. In the 1970's, the populace of the region returns to the old population center, 5 miles from the recreation site. The benefits conferred by the site diminished during the 1950's and 1960's, even though travel (and even total) expenditures associated with the use of the site may have risen during this period.

Both intuition and formal analysis suggest that accurate estimates of benefits conferred by a good or service provide quantitative indices of the availability of good substitutes for the good or service in question. The fewer low-priced substitutes, the greater the benefits conferred by the good. The prices (quantities) of available substitutes may be needed to specify empirically estimated demand (supply) curves. If so, omission of these variables will produce biased estimates of net benefits conferred if the approach used to estimate social benefits is based on the shape and position of an empirically estimated demand (supply) curve. In general, a good grasp of the meaning of both demand and supply (curves) is needed to produce sound estimates of benefits conferred by some commodity. Demand and supply curves are discussed in the following section that deals with various techniques for estimating benefits conferred by outdoor recreation sites.

With wetlands functions and resources, the divergence between large total values and very low (zero) marginal values lies behind much of the controversy as to the appropriate procedure for imputing values to wetlands preservation benefits. If some type of wetland habitat is not a limiting factor in the production of some target wildlife species, the marginal value product of that habitat type is zero. The total social marginal product of the wetlands habitat type or complex may be very large, but if the removal of the last unit does not diminish total output, reallocating the land to more valuable economic activities increases social welfare.

CONSUMER AND PRODUCER SURPLUS AS MEASURES OF NET ECONOMIC BENEFITS AND THE TRAVEL COST METHOD

The commonly used measure of social benefits conferred by a good or service is the area of the triangular region between the horizontal line that extends between the price axis and the intersection of the supply and demand curve (Figure 1). This region, DPP′, is marked by horizontal lines; market expenditures are given by the rectangle OPP′A. This area is called the consumer's surplus conferred by the good or service. The triangular region between this same horizontal line and the supply curve is called the producer's surplus. This region, SPP′, is marked by vertical lines; the horizontal axis measures quantity per unit time, and the vertical axis measures price. Often these two areas are added together to form a total social surplus estimate; but for recreation sites, which are often owned and managed by government agencies, consumer surplus is usually used as the relevant index of social benefits. Since the entrance fee for the site is usually zero or a low nominal value, the ratio of market expenditures to consumer surplus is relatively low; little of the potential consumer surplus is extracted as revenue, and nonmarket benefits conferred by the site can be substantial. Clearly this raises difficulties for recreation economists, since actual market data cannot be used to estimate demand curves for recreation sites. Participation rates for site usage will diminish as recreationists move further away from the site. Hence there is a systematic (inverse) relation between travel costs and per capita trips that has the same general shape as a demand curve. This inverse relation forms the basis of the travel cost method (TCM).

Historically, the estimation of TCM demand curves involves drawing concentric circles around the site, and determining the participation rate and travel cost associated with each of these circular regions. For the circular region closest to the site, the participation rate is highest and travel costs are lowest. For the circular region farthest away from the site, the participation rate is lowest and the travel cost highest. The triangular area under the demand curve, but above a zone's mean travel cost, is taken as the consumer surplus associated with travel cost method estimates of recreation site demand curves. Summation of the consumer surplus over travel zones gives the aggregate consumer surplus estimate (Clawson and Knetsch 1966; Samples and Bishop 1985).

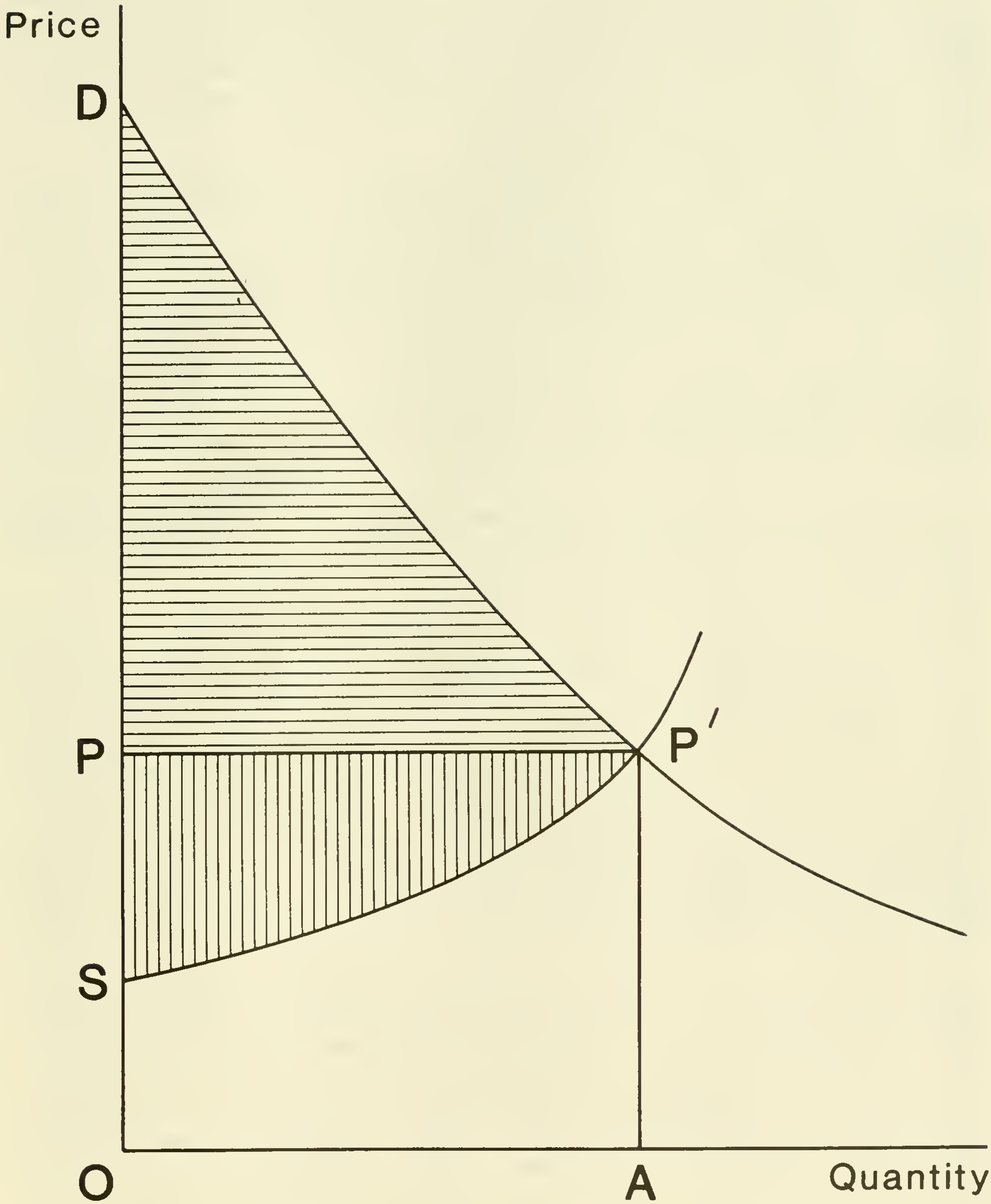

Figure 1. Social benefits estimation using market supply and demand curves.

The travel cost method is based on the estimation of the area beneath an empirical demand curve. In principle and practice, the price of travel or the number of trips to competing outdoor recreation sites may be needed as an independent variable for accurate regression estimates of the travel cost demand curve (the number of trips per thousand residents per annum versus the travel cost). These variables may also be needed to produce unbiased estimates of the net social benefits conferred by the site.

In practice, TCM estimates of benefits conferred are produced by regression estimates of participation rates on a number of independent variables. The key independent variable is the cost of travel to the site. If the travel cost variable is underestimated by the omission of the cost of foregone wages as a component of total travel costs, benefits estimates based on the empirical demand equation will markedly underestimate the true benefits conferred by the site. Other useful independent variables for the estimation of travel cost demand curves include the real income of the households, and socio-economic variables such as the sex of the head of the household and the level of education of the household. To calculate the benefits conferred by the site, all the other independent variables (except for the travel cost variable) are held at their mean value.

The estimated travel cost demand curve can be used for other practical purposes, particularly forecasts of future levels of demand that involve shifts in both demographic and economic variables.

CONCEPTUAL PROBLEMS WITH CONSUMER SURPLUS MEASURES

There are important shortcomings in the traditional consumer surplus concept. Discussion of certain aspects of these defects is beyond the scope of this paper, but it may be useful to note that the Marshallian (Marshall 1920) measures of consumer surplus (the area under the demand curve but above the horizontal price line) are nontransitive with respect to multiple price changes in interrelated markets. When prices in two interrelated markets change, the change in the Marshallian consumer surplus is the sum of the changes in the relevant regions underneath the demand curves of the two goods (Just et al. 1982).

For definiteness, suppose that an exogenous shift in the supply curve of outboard motors leads to a change in the price of outboard motors, in turn causing a shift in the demand (schedule) curve for small boats, and that this latter shift induces a change in the price of small boats. The total change in consumer surplus depends on the sequential order of the analysis; if the consumer surplus change in the market for outboard motors (after the price changes) is estimated first, and then the change in consumer surplus in the boat market is added to this initial value, one value of the total change in consumer surplus emerges from the analysis. But if the sequence of the analysis is changed, and the analysis starts with the motor market first, another value for the consumer surplus results (Just et al. 1982).

It is easy to see that an economic welfare measure that is free of this defect is highly desirable. Hicks (1943) provided two such measures (actually four; however, only two of the measures of consumer surplus that Hicks suggested are widely used today). These two measures distinguish sharply between the level of consumer welfare before and after an economic change.

One of these measures is called the compensating variation. This is the amount of money income that must be taken away from a consumer, after a change in some economic variable, in order to make him exactly as well off as he was before the change took place. The equivalent variation is the amount of money income that must be taken from a consumer in order to make him exactly as well off as he is after the change takes place (under the hypothetical presumption that the change has not occurred). If the change is a fall in price, the compensating variation must be positive (the consumer must lose income if he is to be as well off as he was before the decline in price).

The equivalent variation must be negative (Just et al. 1982) in the case of a fall in price (the two measures will always have opposite algebraic signs). These two estimates of consumer surplus are now known by the generic term of willingness-to-pay approaches to consumer benefits estimates. Natural resource economists have recently developed willingness-to-pay techniques for estimating the benefits conferred by outdoor recreation sites and other natural resource amenity values.

The Hicksian measures are free of the internal defect (non-transitivity for multiple price-income changes) defect of traditional Marshallian consumer surplus. But while it is flawed as a theoretical measure of net benefits conferred, Marshallian consumer surplus is based on market behavior and consumer responses to recorded prices. Since economists have reason to believe that the Marshallian consumer surplus measure provides a very good approximation (Just et al. 1982) to the Hicksian consumer surplus values, the distinction is a moot one for many practical purposes.

Moreover, Willig (1976) has forcefully demonstrated that it is the income effect of a change in price, combined with the non-zero price elasticity of the demand curve, that generates the discrepancy between the Marshallian measure of consumer surplus and the Hicksian measure. The relatively small size of the income effect of the typical change in price implies that the consumer surplus measures will not differ markedly. Willig (1976; see also Just et al. 1982) has also shown that the (change in the) Marshallian consumer surplus calculated from an empirically estimated demand curve for some good or service can be combined with data on the income elasticity for the commodity to yield a more refined approximation to the Hicksian (equivalent variation or compensating variation) consumer surplus measures. However, use of the simple income elasticity adjustment formulas discovered by Willig requires reasonably accurate empirical estimates of the income elasticity of the demand (curve). Unfortunately, natural resource economists have experienced remarkable difficulty in estimating the income effect for travel cost (quasi-) demand curves (Walsh et al. 1987).

It is very useful to understand the conceptual distinction between these two welfare measures in many applied fields, and to have some grasp of the protracted and bitter controversy that once surrounded the Marshallian consumer

surplus measure. In natural resource economics, for example, precise knowledge of the distinction is an indispensable aid in assessing the relative strengths and shortcomings of the contingent value (CVM) and the travel cost (TCM) method. It is difficult to have a working grasp of the terminology of natural resource economics without some knowledge of these two abstract welfare measures, since many natural resource economists refer often (and somewhat loosely) to the CVM estimate of benefits conferred as a Hicksian consumer surplus measure and to the TCM estimate as a Marshallian measure of consumer surplus.

In many fields of applied economics, including natural resource economics, the conventional dichotomy between prices and quantities is blurred by variations in demand and price caused by exogenous quality changes. Succinctly, if quality changes, demand will change along with net social benefits conferred by production and consumption of some market or nonmarket good or service. The problem of estimating quality induced shifts in consumer surplus is interesting from a conceptual perspective because, ideally, the same theoretical constructs (Marshallian consumer surplus and Hicksian consumer surplus) should be used to estimate quality-induced shifts in welfare and price-induced shifts in welfare. A symmetric theory of quality- and price-induced demand and welfare changes was presented by Houthakker (1952).

Houthakker's theory is the basis for the use of the contingent value and travel cost methods to estimate benefit changes generated by qualitative changes at outdoor recreation sites. The critical point is that the analyst need not be greatly concerned with arbitrarily dividing some set of on-site changes into a quality and a quantity component.

Natural resource economists have applied the Houthakker theory in treating improvements in instream flows as a qualitative improvement in site quality (Loomis 1987a); I know of no applications of the Houthakker theory to wetlands, but any change in the quality or quantity of the water resource component of a wetland could be treated as a qualitative shift along lines suggested by recent theoretical developments.

THE CONTINGENT VALUATION METHOD

Natural resource economists use carefully tailored questionnaires called survey instruments to make contingent value method (CVM) estimates of the willingness-to-pay for natural resource amenities. These questionnaires solicit information from respondents by engaging them in a hypothetical bidding game. The recreationist is queried as to the maximum amount he or she would pay rather than give up the use of the site or amenity (this is often simply called the willingness-to-pay of the respondent if there is no possibility of confusion with the theoretical Hicksian measures of consumer surplus). Or he may be queried as to the minimal amount of money he or she would be willing to take in exchange for the use of the site (willingness-to-sell).

The CVM is an important tool for estimating the benefits conferred by on-site quality improvements. One reason for this is that it imposes relatively

modest data requirements for the estimation of net benefits conferred by the exogenous change or improvement. Moreover, the TCM will only capture changes in on-site benefits changes; off-site benefits generated by on-site improvements will not be estimated by a TCM study (Loomis 1987a).

The contingent value method is an important tool for estimating the benefits conferred by qualitative improvements at a wetland site because the data requirements are relatively modest. If the change in the wetland induces a habitat improvement for an economically significant, naturally reproducing species, only a CVM can estimate the increase in off-site (existence) benefits induced by the increase in habitat values (Loomis 1987a). A contingent value method estimate of benefits conferred by a publicly owned wetland recreation site uses survey instruments to provide Hicksian aggregate willingness-to-pay estimates of benefits conferred by estimating the aggregate bid for the site.

The sums of money that a recreationist would exchange for a natural resource amenity are known as bids; the individual bids usually vary by fixed incremental sums. If there is a fixed maximum bid, the instrument is said to be a closed-end bidding game; if there is no predetermined maximum bid, the instrument is said to be an open-end bidding game. There are various techniques for summing over the individual bids to estimate the aggregate net benefits conferred.

Both closed-end and open-end bidding games are fixed-sum bidding games. Roughly, the aggregate bid is the sum of the individual bids. Regression analysis is often used to refine the technique so that the total bid is the product of the "true" average bid (given the socio-economic characteristics of the populace that is making the aggregate bid) times the size of the population. Regression analysis can be used to add elegance and precision to CVM estimates of benefits conferred by qualitative improvements in a wetland site. An independent variable representing the quality change can be introduced into the regression model to estimate the marginal or discrete change in total benefits conferred caused by the quality improvement. Also, the statistical significance of the quality variable provides a valid means of testing the basic premise that aggregate benefits are linked to on-site quality.

Dichotomous bidding games elicit information as to the aggregate bid in the form of a set of probabilities. Thus a respondent is asked to reply with a yes or no to each of a sequence of questions about his willingness to add a certain fixed sum amount to the initial bid. For each incremental sum, there is a probability of eliciting a yes that can be calculated from the responses of the respondents. These probabilities can be used to directly calculate the aggregate bid for the incremental sums. Correction for the socio-economic characteristics of the population is made possible through the use of a qualitative response regression analysis called a logit regression, in which the response probabilities are the dependent variables and the socio-economic characteristics of the population are the independent variables.

Contingent value methods can be tailored to conform to the Hicksian measures of consumer surplus. However, bidding game techniques can only simulate market responses (McKean and Walsh 1986) whereas the Hicksian measures give the true changes in benefits conferred by real changes in prices, quantities, and

qualities. When regression analysis is used to aid in calculating the aggregate bid, the size of the bid is regressed (is the independent variable) on such socio-economic characteristics as race, income, education level, total outdoor recreation days, and travel costs. The mean bid of the populace is then calculated using the estimated regression coefficients. The mean bid times the population size may be used as the estimate of net benefits conferred. However, some researchers use the median bid of the populace (times the population) as the estimate of net benefits conferred. Nonrespondents may be considered as entering a bid of zero dollars, or they may be excluded from the sample.

The principal criticism of the contingent value method is simply that it is not based on actual market behavior. Many economists believe that the benefits estimated with the contingent valuation survey instruments are flawed by several types of bias. These include (Thayer 1981) starting point bias (the size of the initial amount that the recreationist is asked to exchange for his use of the resource may influence the size of his maximum bid); hypothetical bias (the inability or unwillingness of the respondents to predict what they actually would pay if required to do so); and strategic bias (the maximum bids may differ from the true willingness-to-pay of the respondents because the participant may attempt to use the questionnaire to direct the expenditure of public funds). Also, if various qualitative site characteristics such as the abundance and diversity of wildlife confer off-site benefits, the TCM will underestimate the social value of the site (Loomis 1987a), but the CVM captures both on-site and off-site benefits.

The use of this approach to impute off-site values to an outdoor recreation site, however, is controversial. For example, the survey instrument may ask respondents to estimate the existence value of the site. This is the dollar value that is attached by respondents to the fact that the site exists. Nevertheless, the potential of willingness-to-pay approaches to estimate changes in benefits conferred from on-site quality changes strongly suggests that this method will be widely used to value changes in quality variables such as instream flow levels.

THE DISTINCTION BETWEEN FACTORS OF PRODUCTION AND FINAL GOODS AND SERVICES

One of the useful distinctions in conventional economic analysis is that between final goods and services and factors of production (factor inputs) used to produce the final goods (Friedman 1962). The distinction is often vague in conventional and natural resource economics. The services of a waitress in a restaurant is a factor of production from one point of view; but from another vantage point, it is also one of the important services provided by the restaurant. Habitat is a factor input in the production of various target species, such as migratory waterfowl (Hammack and Brown 1974; Lynn et al. 1981; Johnson and Adams 1988). This should mean that habitat has no direct value to the angler or hunter. However, streamflow habitat has been directly valued in a series of recent papers (Walsh 1980; Daubert and Young 1981). I know of no wetlands valuation efforts that use this approach, but Loomis (1987b) has shown

that an on-site recreation values and off-site habitat preservation benefits can be combined in estimating the total social benefits provided by a unique lacustrine resource (Mono Lake in California). Thus direct valuation of habitat is useful and valid for a variety of habitat types (actually Mono Lake has a sizeable wetlands, so it is a peculiarly multi-faceted natural resource).

Prairie pothole wetlands are a limiting factor in migratory waterfowl production (Hammack and Brown 1974). They could be valued directly in much the same fashion as streamflow levels if waterfowl were always hunted on prairie potholes; however, only a fraction of the waterfowl are bagged on prairie potholes, rendering the direct valuation approach useless for imputing habitat provision values to prairie potholes. Wetlands have been valued as providers of habitat for sport (migratory waterfowl) and commercial (oysters, blue crab, and menhaden) target species. Normally, the same habitat should have a greater marginal value product in the production of species that are harvested for sport than for species that are commercially harvested. The reason is that labor is usually the most important factor of production; a larger fraction of the gross receipts for the gross national product accrue to labor than to any other factor of production (Solow 1957). Labor is provided as part of the leisure activity for a sport harvesting activity, so it is considered to be a free good when estimating the marginal value product of habitat.

Thus labor cost is not explicitly treated as a factor of production in sport harvesting production function models (Hammack and Brown 1974), thereby increasing the fraction of total outlays (willingness-to-pay) that can be allocated to habitat and other factors of production. However, labor must be treated as a factor input in production function models of commercial harvesting activity (Lynn, Conroy, and Prochaska 1981); labor's share sharply diminishes the share of gross receipts that can accrue to habitat and, roughly, the estimated marginal value product of habitat. Also, the value of a species is generally greater when bagged for sport (Peters, Ahrenholz, and Rice 1978) than when taken commercially.

The distinction between gross and net economic activity is an important issue in the estimation of an economic production function. The sport fishing versus commercial harvesting example shows clearly that the appropriate treatment of a factor of production is often more than a matter of the correct accounting procedure. The distinction between gross and net outputs and inputs in a social production process is integral to many economic analyses, and in many specific instances reflects considerable imagination and creativity by the analyst.

The distinction between net benefits conferred by the site and total expenditures incurred by the community underlies the example given earlier in which total travel cost expenditures for a specific site might rise, but net benefits conferred might fall. The distinction between net and gross values is fundamental in economic analysis, and it is often a bit more complex than noneconomists suppose. In this particular (travel cost) example, there is obviously only one correct distinction between gross and net benefits and gross and net value. But, the definition of the good or service produced by some economic activity may depend on the purpose of the analysis or on data limitations. For example, travel time to-and-from the site can be treated as a factor input in a household production function producing an on-site

recreational experience (Lancaster 1966). Or the trip itself can be treated as consumption good; once the analytic framework and commodity definition is chosen, a consistent accounting framework emerges that dictates the way in which the economist must distinguish between net and gross economic value. If the trip itself has direct value, then all trip related expenses yield direct utility and produce net social economic value. If the commodity is the on-site recreational experience, all expenses above some bare minimum can be ignored (netted out) in estimating the net economic benefits produced by the experience and the outdoor site.

COMMON ECONOMIC TERMS

Six important terms that are often used in natural resource allocation discussions follow:

Demand curve. Obviously, it would take a textbook to fully define contemporary versions of the concepts of supply and demand. Certain aspects of these terms are briefly reviewed here (Friedman 1962). The demand curve depicts the maximum price that a group of consumers will pay for the offered quantities. Therefore, one should think of the demand curve as dividing the plane into two regions. The first (which lies between the demand curve and the two axes) is a set of attainable price-quantity combinations. The second (which lies above and to the right of the demand curve) is unattainable in the sense that consumers will not pay the higher prices for these larger quantities.

The demand curve is defined for some fixed period of adjustment between the various points on the curve. The larger the period of adjustment, the flatter (more elastic) the demand curve. The elasticity of the demand curve is usually thought of as reflecting the number of close substitutes available in the market place for the good in question; the more close substitutes, the flatter the demand curve. The demand curve usually depicts a rate of purchase (tires purchased per week, month, or year). Certain items, however, such as paintings by artists who are no longer living, are relatively fixed in supply. In these cases, the demand curve does not have a time dimension and is called a stock demand curve.

Though demand curves almost always have a negative slope, this fact cannot be deduced from first principles (such as the utility maximization hypothesis). They invariably slope downward because a fall in price makes purchasing substitutes less attractive (the substitution effect) and increases the real income of consumers (the income effect). Both effects operate in concert to give the demand curve its downward slope.

Supply curve. The usefulness of the supply-demand framework stems from the fact that the social forces that shift demand curves often have a negligible effect on the supply curve (and vice versa). The supply curve depicts the maximum quantity that will be forthcoming at the designated price. Hence one should also think of the supply curve as dividing the plane into attainable and unattainable areas. Again, the specification of time for both the rate of

production (output per day, week, month, or year) and the period of adjustment allowed for the suppliers to respond to different prices is a critical determinant of the shape of the curve.

The supply curve usually has an upward slope, though exceptions to this rule are more important than (the corresponding exceptions) for the demand curve. A negatively sloping supply curve may be a consequence of downward sloping supply curves for the individual firms. In this case, the industry may become dominated by the most efficient firm (a monopoly will eventually control output and price). If the supply (marginal cost) curves of the individual firms are upward-sloping, and the negative slope of the industry supply curve reflects economic forces that are external to the individual firms, then the competitive output and price will not be socially efficient. But the industry will tend to be competitive; there are no obvious forces that will cause one firm to control output.

Production frontier. This is a concave curve that depicts the technologically determined (variation in the) rate of trade-off between goods A and B that society faces. This curve shifts with changes in society's resource endowment.

Aggregate production possibility set. Given a fixed, finite level of resources, society can produce only finite amounts of any good or finite bundles of goods and services. The specification of the relation between available inputs and attainable outputs designates the aggregate production possibility set.

Marginal product. The increase in total output from using one additional unit of some specific factor of production holding all other factors of production constant. This increase, except in special cases, is related to the quantity of the other inputs, the level of output, and the quantity used of the factor in question.

Marginal value product. The increase in the value of the total output from using one additional unit of some factor of production holding all other factors of production constant. If the marginal value of output is a constant independent of the quantity of output there is little distinction between marginal value product and marginal product except for the difference in the units in which they are measured. But if the product or service is unique (such as the services conferred by an outdoor recreation site), there may be a divergence between the two induced by the change in the marginal value of output from the production of an additional unit.

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This was an early attempt to value wetlands. The authors impute a net value for preservation benefits of New York State wetlands of about $350 to $400 per acre (capitalized value of annual flows with a 5% discount rate). The result is intuitively appealing, but the estimation procedure does not distinguish between consumer surplus components and net expenditures estimates.

2. Cain, S.A. 1966. Estuaries: a neglected resource complex. Commercial Fisheries Review 28(10):27-34.

The author is a former Assistant Secretary of the U.S. Department of the Interior. He gives a useful description and qualitative assessment of the socially beneficial functions performed by estuarine wetlands, including habitat provision for valuable shellfish and finfish species. Cain's description of the divergence between legislative intent and bureaucratic action is as apt and relevant today as it was 20 years ago.

3. Carley, D.H., and C.M. Frisbie. 1968. The blue crab, oyster, and finfish fisheries of Georgia--an economic evaluation. Georgia Game and Fish Commission. Contributions series No. 7. 13 pp. [Available from Library, Georgia Dept. of Natural Resources, Coastal Resources Division, 1200 Glynn avenue, Brunswick, Georgia 31523.]

This is a concise, informative paper on the commercial finfish and shellfish harvests of the tidal marshes of Georgia. Carley and Frisbie chart the price of oysters (for 1957-1968), blue crab, and certain commercially valuable finfish species. Some estimates of the jobs provided by these fisheries are provided, but the emphasis is on prices and total catch (value and quantity), not multiplier effects.

4. Goldstein, J.H. 1971. Competition for wetlands in the midwest: an economic analysis. Johns Hopkins University Press, Baltimore. 105 pp.

This report is one of the seminal studies on wetlands. It deals with the economics of drainage of Minnesota prairie potholes; the estimation of the social marginal physical product of prairie potholes in the production of migratory waterfowl; the estimation of multi-site, multi-origin travel cost method benefits-and-demand function(s) for the hunting of migratory waterfowl in Minnesota; the role of government subsidization of farmland drainage in prairie pothole conversions; the level of expenditures for leasing rights for hunting purposes on Minnesota farmlands; and the optimal social allocation (farming or

migratory waterfowl habitat) of prairie potholes. No brief resume can convey the care with which the author handles the complex web of details underlying each of these issues. However, two examples must be cited; namely, the excellent discussion of wetland typology and the profitability of wetland drainage, and the documentation of the fact that prairie potholes are more productive than the lacustrine wetlands and myriad lakes of central and north-central Canada in the production of migratory waterfowl.

For certain types of prairie potholes, drainage is unprofitable at the prevailing (1971) farm support price and drainage subsidization levels. Drainage of small seasonal (class 1 and 2) potholes in southern Minnesota tends to be quite profitable and would remain profitable in the absence of all government agricultural support payments. The drainage of large, permanent marshes in northwestern Minnesota is not always profitable even with strong Federal price support, crop disaster insurance, and low interest loan programs.

Waterfowl can breed in the vast region that lies directly to the north of the prairie pothole region. Documentation of the net marginal productivity of prairie potholes in the production of migratory waterfowl involves complicated research resting on numerous disciplines. The U.S. Fish and Wildlife Service gathered much of the bird count data, performed certain field experiments documenting the recruitment class versus number of wetlands relation, and did much of the statistical modeling Goldstein uses to demonstrate the validity of the hypothesis that prairie pothole wetlands produce waterfowl.

5. Brown, G.M., Jr., and J. Hammack. 1972. Dynamic economic management of migratory waterfowl. The Review of Economics and Statistics 15(1):73-80.

This justly famous article, the forerunner to the book by the same authors (see [10]), treats prairie pothole wetlands as a factor input for a productive process in which the output is migratory waterfowl. Adult breeding waterfowl are the other factor input in the estimated aggregate production function. The benefits provided by the duck population stem from the consumption of ducks by hunters. The instantaneous gross aggregate benefits conferred is a function of the number of ducks bagged, the hunters' income, and various taste variables. Net benefits are gross benefits minus a social cost term, where social costs are an increasing convex function of the number of nesting ponds in south-central Canada.

The authors find that at 1974 easement payment levels for Canadian prairie potholes (about $5 per annum per pond), the socially optimal amount of Canadian prairie pothole acreage is about 20 times the historical average. At somewhat higher easement costs ($12-$17), the model calculates the socially optimal number of Canadian breeding ponds to be 5 times the historical average.

6. Gupta, T.R. 1973. Economic criteria for decisions on preservation and alteration of natural resources with special reference to freshwater wetlands in Massachusetts. Ph.D. Thesis. University of Massachusetts, Amherst. 271 pp.

Gupta studies the impact of recent Massachusetts legislation designed to limit drainage and filling of wetlands. He describes the institutional forces

and individual incentives generating wetlands loss, and he estimates the social preservation benefits and opportunity costs for Massachusetts wetlands. He uses these estimates to develop criteria for granting conversion permits. Gupta believes that fill and conversion permits should be granted by the State if the net market benefits from drainage outweigh the nonmarket preservation benefits. Roughly, conversion returns span a \$300-\$70,000 per acre (capitalized value) range, while preservation benefits lie somewhere in the \$300-\$60,000 per acre range.

7. Haslam, S.M. 1973. The management of British wetlands: part I. Journal of Environmental Management 1(1):303-320.

This paper presents no formal economic analysis or new quantitative economic data. The author lists the wide variety of wetland outputs (for example, reeds for thatched roofs) that man has learned to use throughout the ages. Given suitable changes in technology, man may one day find wide use for the store of natural products provided by the globe's wetlands.

8. Pope, R.M., and J.G. Gosselink. 1973. A tool for use in making land management decisions involving tidal marshland. Coastal Zone Management Journal 1(1):65-74.

This is one of the papers that formulates an energy theory of value for estimating the total social loss from drainage and conversion of tidal wetlands. The energy theory of value estimates net preservation benefits for acres of tidal marshland as the per acre fuel oil equivalent of the solar energy embodied in the production of above ground plant biomass ("ecosystem life support functions"). The authors also develop a tertiary waste treatment social benefits conferred estimate for tidal marshland acres.

They apply the two sets of wetlands preservation benefits estimates--\$2,500 per acre per annum for the tertiary treatment function, \$4,150 for the life support function--generated by these valuation techniques, to the problem of estimating the true social opportunity cost of building a four lane highway through a marshland.

9. Gosselink, J.G., E.P. Odum, and R.M. Pope. 1974. The value of the tidal marsh. Louisiana State University, Center for Wetlands Resources Report No. LSU-SG-74-03, Baton Rouge. 30 pp.

Gosselink, Odum, and Pope, define and value the "ecosystem life support functions" introduced by Pope and Gosselink (see [8]). This paper, like the earlier work by Pope and Gosselink, also uses a single factor theory of value. Hence, it is hardly surprising that Gosselink, Odum, and Pope find preservation benefits for tidal marshes that are much larger than those obtained through conventional analyses. The entire per acre per year values of the finfish and shellfish harvests of the tidal marshes of various southern Atlantic coastal States is imputed to the marshes. All of the private outlays for hunting and sport fishing are also imputed to the marshes. The resulting average marginal product for this amalgam of outputs and services was estimated to be about \$100 per acre per annum (in early 1970's dollars) for all the regional tidal marshes.

Large numbers are imputed to tidal marshes for three types of oyster aquaculture, including moderately intensive oyster aquaculture ($630 per acre per year), intensive oyster aquaculture ($1,575 per acre per year), and intensive raft aquaculture ($6,125 per acre per year). Again, these represent the average value product of the marshes under the assumption that the marginal value product of the other factors of production, including labor, are equal to zero. Gosselink, Odum, and Pope make very little of the important distinction between complementary and noncomplementary outputs provided by the marshes. Clearly, the use of a marsh for aquaculture restricts provision of substitute goods and services, such as tertiary waste treatment. But the authors do not add the value of the aquaculture outputs to the value of the other (potential) outputs. The panoply of outputs and values is completed by the imputation of a $2,500 per acre figure for the alleged tertiary treatment output by tidal marshes and the imputation of a $4,100 per acre value for the ecosystem life support function. The ecosystem life support value is derived by using their estimate for the price of energy. The fossil fuel needed to release 10 kilocalories (10,000 calories) costs a dollar according Gosselink, Odum, and Pope. Thus the energy equivalent of 10,000 kilocalories is a 1973 dollar. The life support functions are essentially the same as in the paper by Gosselink and Pope; they represent the conversion of solar energy into above ground plant biomass. However, the discussion given in this article is a bit more complex because the authors believe that some ecosystem life support functions, such as geochemical cycling, are not captured by the narrow definition they use to determine the social opportunity cost of wetlands loss. It is clear that the value of many of the other human uses (recreation, tertiary waste treatment) can be added to the value of the life support function, but an extended discussion of this tricky subject would remove considerable ambiguity from their terse treatment.

10. Hammack, J., and G.M. Brown, Jr. 1974. Waterfowls and wetlands: toward bioeconomic analysis. Johns Hopkins University Press, Baltimore, MD. 95 pp.

This is one of the cornerstones of bioeconomics. Hammack and Brown treat prairie potholes as a factor input in the production of migratory waterfowl. The methods, data, and conclusions are essentially the same as those reached in their Review of Economics and Statistics article (see [5]). The book, however, includes a more extensive background discussion of consumer surplus, the contingent valuation method (CVM), mallard duck population dynamics, and other management-oriented models of migratory waterfowl population dynamics.

Hammack and Brown estimate linear and nonlinear production functions for mallards with a regression model based on data for the number of Canadian prairie potholes. They assume that the same production relation can be extended to all North American waterfowl and all North American prairie potholes. The contingent value method survey instrument that they used to establish the willingness-to-pay for bagged waterfowl (above and beyond expenses) was only administered to Pacific flyway hunters; the authors assume that the quantitative results can be extended to the entire U.S.

Aerial counts of the number of May and July prairie potholes were used to establish annual time series data of the number of breeding ponds for the period from 1955 to 1968. The July ponds estimate is, according to Hammack and Brown,

the more useful index of habitat because May ponds often go dry by July; breeding waterfowl are forced to move elsewhere when this happens. Thus the best index of available habitat is the number of July ponds. Extensive bird counts established the number of adult ducks returning to the prairie potholes each spring as well as the size of the recruitment class for the 1955-1968 period. The marginal physical product of prairie potholes was established from the estimated coefficient for the number of ponds in a regression model in which the size of the annual recruitment class was the dependent variable. The size of the adult population was the other independent variable in this multivariate regression model.

Waterfowl breeding habitat has been declining rapidly during the postwar years. In 1955 there were 5 million July ponds; in 1968 there were only 850,000 July ponds. The estimated marginal physical product of a pond was 2.2 birds; since the estimated willingness-to-pay for a bagged waterfowl was $3.29 (1974 dollars), the estimated marginal value product of a Canadian prairie pothole was $8.88. The cost of an annual easement fee for a Canadian prairie pothole was estimated to be $4.73 for all Canada in 1974 dollars. Using this cost and output data, Hammack and Brown estimate that the socially optimal number of prairie potholes is between 5 and 20 times the historical average. The historical average is the average number of July ponds for the 1961-1968 period, 1.3 million.

11. Gupta, T.R., and J.H. Foster. 1975. Economic criteria for freshwater wetland policy in Massachusetts. American Journal of Agricultural Economics 57(1):40-45.

The authors present some original techniques for estimating benefits conferred by various functions performed by Massachusetts wetlands. The socially beneficial functions include wildlife habitat provision, visual aesthetic benefits, groundwater recharge (water supply), and flood prevention and amelioration. The most interesting valuation procedures are those for wildlife habitat provision and visual aesthetic amenity values. To estimate the benefits conferred by wildlife production, Gupta and Foster analyzed the prices paid for wetlands by the Massachusetts Division of Fisheries and Game for more than 8,000 acres bought during 1969-1971, to estimate per acre benefits conferred by these land parcels.

The five highest prices paid for wetland parcels ranged from $584 to $2,387 per acre. Thus Gupta and Foster concluded that the capitalized value of per acre wildlife habitat provision by wetlands was the most representative price paid for these land parcels; they chose $1,200 per acre as the representative price of the wetlands producing the highest per acre wildlife production benefits. Thus $1,200 is, according to this methodology, the capitalized wildlife benefits provided by the wetlands that are most productive with respect to this particular function. After adding in an appropriate figure ($100) for the cost of operation, Gupta and Foster convert the $1,300 capitalized value into a $70 per annum net benefits flow by multiplying by a 5.375% discount rate. The valuation methodology was extended by Gupta and Foster to encompass wetlands with varying degrees of productivity with respect to wildlife habitat provision. They accomplish this by establishing a point scoring system for wildlife habitat

provision, and then they convert the points into a net annual benefits score using $70 as the base figure for a 100% score.

They use a similar methodology for estimating visual amenity values conferred by wetlands. They examined the prices paid by 29 municipalities for various land parcels to establish the baseline price of a wetland scoring 100% on a visual-cultural score point system. The water supply and flood control benefits were established in more conventional fashion. They used U.S. Geological Survey data to estimate a cost differential between water produced from yields produced by aquifers recharged by wetlands, and water produced from well fields in the north Atlantic region. This cost differential was used to estimate a capitalized and a net discounted annual benefits estimate. The water supply point scoring system distinguishes a high ($2,800), medium ($1,400), and low ($400) benefits level.

A three-tier point scoring system was established for the flood prevention function using U.S. Army Corp of Engineers data for the Charles River basin. Gupta and Foster suggest that the total preservation benefits of any wetlands can be estimated by use of the point scoring systems. Whenever the preservation benefits of some wetlands are higher than the benefits conferred by some project involving drainage of the wetlands in question, the project should be abandoned.

12. Larson, J.S. 1975. Evaluation models for public management of freshwater wetlands. Pages 220-226 in K. Sobel, ed. Transactions: Fortieth North American Wildlife and Natural Resources Conference. Washington, DC.

The author provides a framework for imputing various (levels of) qualitative preservation benefits of the Nation's wetlands. This has meaningful operational content from a management perspective because of the prohibitive cost of a close examination of the preservation benefits of any particular wetland. Larson offers a three-tier management-oriented wetland assessment format. The first tier deals with distinguishing between "outstanding wetlands" and those wetlands that do not fall into the exceptionally noteworthy category. The defining characteristics of the exceptional wetlands are highly variegated; they include habitat provision for rare flora and fauna, habitat provision for exceptionally beautiful flora, outstanding and unusual geomorphological features, and the use of the wetlands as habitat by large numbers of water-, marsh-, or shore-birds.

The other two tiers provide an economic model for imputing wetlands preservation benefits, and a qualitative framework for assessing the nonmarket outputs of wetlands that do not belong in the exceptional category. The economic model imputes benefits to groundwater recharge and reviews the acquisition costs of various wetland types. The qualitative assessment model covers a variety of outputs, including habitat provision for wildlife, potential for groundwater recharge, and visual impact. The author restricts his discussion to the glaciated inland freshwater wetlands of the northeastern U.S.

13. Batie, S.S., and W.E. Cox. 1976. Economic implications of environmental legislation for wetlands. Virginia Polytechnic Institute and State University. Dept. of Agricultural Economics Research Report No. 29, Blacksburg. 16 pp.

The authors give a brief history of National and State wetland legislation. This history nicely illustrates the broad premise that attaining the social goal of wetlands preservation has gained ascendancy over the competing goal of using the (wetland) land base of the Nation to maximize the private pecuniary returns from various development activities.

Batie and Cox point out that the various permitting programs of the U.S. (Section 404 of the Federal Water Pollution Control Act Amendments of 1972) and the States of Virginia and Maryland have social costs (private development activity foregone) as well as important social benefits. They use site-specific examples to show that there are trade-offs between development and preservation costs and benefits. They are particularly concerned with the loss of economic activity from the restriction of beach-front building activity in Virginia and Maryland after the enactment of recent regulatory permitting programs. They suggest that a development potential wetland classification system might play a role in obtaining the optimal social mix of wetland preservation and development.

14. Brown, R.J. 1976. A study of the wetlands easement program on agricultural land values. Land Economics 52(4):509-517.

This paper discusses the effects of the easement purchase program of the U.S. Fish and Wildlife Service on farmland prices in five counties in North Dakota, and four in South Dakota. The easement purchases discussed here are permanent; some authors use the term "easement payment" to describe the annual rental fee that the Government pays the farmer to forego wetland drainage regardless of the duration of the leasing arrangement.

When farmland for which a permanent easement lease exists is sold, the new owner is not able to drain the land that is under easement. Thus the potential productivity of the land (for farm outputs) is diminished by the easement agreement. This should and does show up as a statistically significant factor underlying the variation in farmland prices. In fact, when the loss in earnings from easement arrangements is important (the land has high earnings potential and productivity), the earnings foregone are fully deducted from the price of farmland. These rough calculations are made possible by drainage cost estimates provided by various experts. The author uses a value of $17 per annum per acre as a representative easement fee value in investigating the optimal allocation (habitat provision for migratory waterfowl or farmland) of prairie pothole wetlands. At this easement fee price, if the drained farmland has a market value of less than $393 per acre, the land should remained unconverted if it is to provide the maximum social benefits. Hammack and Brown (see [10]) estimated that at a price as high as $17 per acre per annum the socially optimal allocation of wetlands called for an expansion of wetland acreage that is roughly five times the historical average.

15. Carriker, R.R. 1976. Economic incentives for institutional change: the case of the Virginia wetlands act. Ph.D. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 153 pp.

This is an interesting attempt to show that wetlands preservations benefits exhibit increasing returns; the social benefits conferred per unit of wetland

acreage are alleged to increase as the number of wetland acres increase. On the other hand, the author believes that the average returns to private development and drainage of wetlands exhibits diminishing returns. Carriker believes that high per acre wetlands preservation benefits (coupled with increasing returns to wetlands preservation) underlie the enactment of the Virginia Wetlands Act of 1972. This act seeks to protect ecologically productive Virginia wetlands from development activities. Carriker provides empirical estimates of the dollar values of returns to development activities as well as the per acre social benefits conferred from the use of publicly owned wetlands for various activities, such as recreational saltwater fishing.

16. Hill, D. 1976. A modeling approach to evaluate tidal wetlands. Pages 105-116 in K. Sobel, ed. Transactions: Forty-first North American Wildlife Management Institute. Washington, DC.

The author discusses the amenity values provided by Atlantic estuarine and coastal salt marshes of North America. These benefits are not quantified for a real coastal wetland, but for a computer model of a wetland. The model consists of a set of equations that define uses and values for biological, physical, and chemical functions performed on Hypothetical Bay. Uses and outputs include preservation of certain grasses (*Spartina alterniflora*); building and operating a marina; clam, mussel, and sea worm harvesting; cod and flounder harvesting; oyster harvesting; filling in the *Spartina* acreage; and discharging waste-water into the bay.

The highest per acre yield is provided by the construction of a marina to support a cod-flounder fishery. But the salt marsh would not support a cod-flounder fishery due to biological and physical constraints. The most valuable *feasible* benefits provided by the salt marsh are generated by growing certain grasses and harvesting clams and seaworms. Thus some of the uses of Hypothetical Bay can be sustained indefinitely, others cannot. The author imputes preservation benefits for the grasses at $317 per acre for the *Spartina* alone; the other grasses provide an additional $225 per acre. The model computes the changes in the values of the outputs with changes in the various inputs.

17. Luken, R.A. 1976. Preservation versus development: an economic analysis of San Francisco Bay wetlands. Praeger, NY. 155 pp.

Luken assesses the opportunity costs of foregone development for extant San Francisco Bay area wetlands. He does not tackle the difficult problem of imputing quantitative preservation benefits for these wetlands based on such nonmarket wetland outputs as habitat provision for shellfish and finfish. The author finds that only a fraction of these wetlands (49,000 acres out of a total 435,000 acres) have high development potential, primarily because of high conversion costs or because the lands are already publicly owned. The latter obstacle (high conversion costs due to public ownership) seems a bit out of place in a study of the optimal allocation of resources.

18. Friedman, J.M. 1977. The growth of economic values in preservation: an estuarine case study. Coastal Zone Management Journal 3(2):171-181.

The Office of Coastal Zone Management of the U.S. Department of Commerce and the State of Oregon proposed, in the spring of 1974, that the south slough of Coos Bay become the Nation's first estuarine sanctuary. The proposal would allow the State to acquire 4,500 acres of wetlands and uplands, and commits $1.6 million to acquire the privately owned portion of the 4,500 acres. Friedman estimates the costs and benefits of preservation of this 4,500-acre region as an estuarine sanctuary. Unfortunately, some of the empirical data needed for the estimation of the preservation benefits is lacking.

The principal social opportunity cost of preservation is income foregone from timber harvesting on the south slough; the present value of these lost receipts is $1.124 million. The market value of the private land and buildings on the proposed site is $517,000, so the total social opportunity cost is $1.641 million (using an 8% discount rate). The author argues that the benefits of preservation will grow over time due to increases in total demand for the nonmarket outputs provided by the sanctuary. This growth in benefits stems from two factors. First, the growth in demand will be generated by regional population and income growth. Second, the supply of amenity values provided by the site is rigidly fixed (perfectly inelastic).

The basic analytic framework for this argument was provided by Fisher, Krutilla, and Cichetti (1972; The economics of environmental preservation, American Economic Review 62(4):605-619). The author offers a set of detailed calculations that show the decisive impact of the rate of growth in benefits on the cost-benefits ratio of the proposed acquisition. If the rate of growth in benefits is 0.205%, benefits equal opportunity costs. If the rate of growth in benefits is 5%, the net value of preservation is $959,000.

The argument by Fisher et al. is certainly plausible, but it also needs some empirical testing. Growth in total (on-site plus off-site) benefits may be limited by shifts in the income elasticity in the demand for the amenity values offered by the sanctuary. Growth in on-site benefits may be limited by congestion costs. Nevertheless, this argument by Fisher, Krutilla, and Cichetti has not been sufficiently widely noted by environmentalists and resource management professionals. Nonmyopic imputation of social marginal preservation benefits of wetlands may have markedly more conservationist policy implications than the conventional myopic estimates.

19. Hill, D. 1977. Linear programming model to quantify economic, environmental, and social values of a tidal marsh. Ph. D. Thesis. Columbia University, New York. 137 pp.

Hill assembles a linear programming model that could be used to derive the socially optimal mix of market and nonmarket outputs for coastal wetlands. The known benefits of a typical coastal salt marsh are used to estimate the coefficients of certain linear activities for the model. However, Hill admits that since a number of the nonmarket benefits cannot be quantified, in practice the model is used to estimate the range of values that nonmarket outputs must assume if the preservation benefits of the coastal salt marshes are to equal the market values of the resource.

20. Leitch, J.A., and D.F. Scott. 1977a. A selected annotated bibliography of economic values of fish and wildlife and their habitats. Agricultural Economics Miscellaneous Reports No. 27. Dept. of Agricultural Economics, North Dakota Agricultural Experiment Station, North Dakota State University, Fargo. 132 pp.

The first section of this annotated bibliography contains a 111-reference bibliography of wetlands economic literature. Leitch is a professional economist, and the discussion that accompanies the annotation is expert and incisive. The discussions are terse, but usually convey at least the subject matter of the referenced text.

21. Leitch, J.A., and D.F. Scott. 1977b. Economic impact of flooding on agricultural production in northeast central North Dakota. Department of Agricultural Economics Research Report No. 120, North Dakota Agricultural Experiment Station, North Dakota State University, Fargo. 57 pp.

The study area for this report is really the Devil's Lake basin region of North Dakota; this is a part of the Red River drainage basin. The drainage pattern of this closed basin includes numerous streams and some shallow lakes near the lower end of the basin. The lakes are interconnected by some of the streams. During the spring runoff, streamflows exceed channel capacities, and the overflow floods thousands of acres of adjacent cropland. Summer thunderstorms can also cause flooding of nearby farmlands. These floods cause significant crop losses and other types of damage to farms located in the region. Attempts to develop flood reduction plans for the basin have not been completely successful. The failure to completely implement these flood reduction plans is partly due to the fact that the flooded zones provide nationally significant nonmarket amenity values by providing wetlands and wetland habitat for migratory waterfowl.

The North Dakota State Legislature recognized the need for a flood reduction plan that would reconcile environmental and farm interests, and it passed a 1975 bill to create a Devil's Lake Basin Advisory Committee. The committee was charged with developing a water resource conservation plan for the basin. Leitch and Scott used two questionnaires to investigate farmers' attitudes toward wetlands and the dollar value of total flood damages and flood-related income losses. The first questionnaire was administered to a large group of farmers in the Devil's Lake basin region; the second was a more detailed follow-up to the first that was used to establish quantitative per acre flood-related damages. The per acre flood-related damage estimates for the Devil's Lake basin farmers was $8.71 (1974 dollars), using long run agricultural output price relations, and $13.03 (1974 dollars), using 1974 price relations. Damages to nonagricultural property were not included in these estimates. The flood frequency used to estimate the annual damage was 0.3. Flood insurance and disaster payments were deducted from the per acre farm damage estimates. The respondents indicated a desire to drain about 36% of the wetland acreage on their farms; this wetland acreage totaled to 6% of their total crop acreage. Half of the respondents indicated that they suffered wildlife related damages.

22. York, D.W., B.C. Dysart, III, and L.W. Gahan. 1977. Modeling multiple-use in natural areas: part II--the Santee Swamp study. Water Resources Bulletin 13(2):283-295.

This paper presents a management-oriented activities model designed for maximizing the market and nonmarket social benefits conferred by the Great Santee Swamp of South Carolina. This 18,000-acre bottomland hardwoods region was the subject of controversy stemming from a proposed timber harvesting contract. The timber harvesting activity would (according to environmentalists) diminish the amenity values from various recreational activities pursued on the swamp, including hunting and fishing. The swamp offers striped bass, largemouth bass, crappie, and bream fishing to the sportsman. Duck hunting was reputed to be excellent in the late 1970's.

Numerical parameters were estimated for a net benefits model that included the market prices of the timber yield, option values (for nonmarket outputs), interaction effects between recreational activities and timber harvesting, regional income and employment multiplier effects, and suitable cost terms. Some timber harvesting was socially optimal according to the activities model, but the optimal harvesting rate was only 64% of that proposed in the timber harvesting contract. The optimum management activity strategy was relatively insensitive to perturbations of the option values and interaction effects, but quite sensitive to the values chosen for the regional income and employment multipliers.

23. Batie, S.S., and J.R. Wilson. 1978. Economic values attributable to Virginia's coastal wetlands as inputs in oyster production. Southern Journal of Agricultural Economics 10(1):111-118.

Batie and Wilson attempt to quantify the habitat provision benefits provided by coastal wetlands in the commercial harvesting of oysters. Batie and Wilson estimate the marginal value product of coastal wetland acreage in a cross-section regression model in which the weight of the 1969 harvest by the 17 Virginia coastal counties is the dependent variable. The independent variables are the 1969 harvest effort for each of the 17 coastal counties, number of acres of leased oyster grounds by coastal county in 1969, number of acres of open access property oyster grounds (by coastal county in 1976), number of coastal wetland acres (by county in 1969), and a dummy variable to represent salinity levels.

Some of the assumptions underlying the model include: (1) oysters are presumed to be harvested in waters adjacent to the counties where the harvest data are reported; (2) all of a county's wetlands contribute uniformly to the production of oyster biomass, and harvest is solely determined by effort and biomass production; (3) the effort variable is adequately quantified by adding together the number of oyster tongs in a county and the number of oyster dredges and multiplying the sum by a constant (0.52688); and (4) the variation in oyster harvesting man-hours across counties is nil.

Oyster biomass produced in any year is a function of many variables, including water temperature, disease levels, predator pressure, water quality, and salinity. Also, the relation between wetlands and oyster biomass is complex.

The quality of the wetland acreage may be more important than the quantity of the wetland acreage; the relation between acreage and biomass is plausible but not based on scientific evidence. Yet the Batie-Wilson model only includes two biological (environmental) variables, wetland acreage and the dummy variable for salinity level of the coastal waters of the county. This dummy variable was zero or one; the dividing line between high and low salinity coastal waters was 17 ppt.

The authors indicate that salinity level may be the most important independent variable limiting oyster biomass production because high salinity water precludes the presence of important oyster predators. Oysters are harvested by tongs or by dredge, but dredges are more efficient than tongs. The particular specification of the effort variable was determined by the use of principal components analysis.

The marginal product of wetland acreage was determined by the estimation of a Cobb-Douglas production function and differentiation with respect to the wetland variable. A discounted marginal value product was determined by multiplying the marginal product of wetland acreage by the dockside price of oysters, then dividing by the discount rate of 10%. The discounted marginal value product of a wetland acre was estimated for various counties; it varied from $11 to $1,414.

24. Chabreck, R.H. 1978. Wildlife harvest in wetlands of the United States. Pages 618-631 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetland functions and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal agencies and the American Water Resources Association, Minneapolis, MN.

This paper contains some interesting information on migratory waterfowl harvests. Some of the information presented, such as that on the distribution of the waterfowl harvest by flyway, renders Chabreck's paper a useful supplement to the work of Hammack and Brown (see [10]) on the social marginal value product of prairie potholes. Chabreck also introduces some data on the fur-bearing and alligator harvests in Louisiana.

Louisiana is the leading fur-producing State. During the 1976-1977 season Louisiana trappers and landowners received $24.1 million from the sale of pelts, and $0.6 million from the sale of meat. About 85% of the various animals were harvested from wetlands; major wetland-dependent fur-bearing species include nutria, muskrat, mink, raccoon, and river otter. The value of the harvest per thousand acres of coastal marsh and swamp totaled $13,300. The value of the total alligator harvest is not reported here, but the author does estimate the number and value of alligators harvested--12.1 and $1,114 respectively--per 1,000 acres of wetland in Cameron and Vermilion Parishes.

25. Foster, J.H. 1978. Measuring the social value of wetland benefits. Pages 84-93 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetlands functions and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal agencies and the American Resources Association, Minneapolis, MN.

Foster discusses the difficulties of imputing dollar values to wetlands preservation benefits. In particular, he discusses the work of Larson, Gupta, and Foster (see [11] for a discussion of the work of Gupta and Foster, and [12] for a discussion of the work of Larson); Gosselink, Odum, and Pope ([9]); and Batie and Wilson ([23]). The innovative work of Larson, Gupta, and Foster uses the collective expertise of a group of wildlife biologists, hydrologists, landscape architects, and economists to impute dollar values to four types of inland freshwater benefits, including the provision of wildlife habitat, municipal water supply, visual-cultural benefits, and flood control benefits.

Foster argues that economists and ecologists who estimate wetlands preservations benefits do not make sufficient allowance for variations among wetlands in terms of the functions they perform. Nor do they allow for the wide variation in the physical productivity of wetlands performing the same beneficial functions. In particular, Foster is very concerned with valuing "unique" wetlands.

26. Jaworski, E. and N. Raphael. 1978. Fish, wildlife, and recreational values of Michigan's coastal wetlands. Phase I. Michigan Department of Natural Resources Report, Land Resources Program, Lansing. 225 pp.

Jaworski and Raphael make a thorough inventory of the distribution of Michigan's coastal wetlands resources. Not only do they estimate the areal extent of the remaining wetlands, they also provide extensive data on the rate of loss of coastal wetlands. They also inventory the social benefits and values provided by these wetlands. The technique used to impute value to wetland acreage is, unfortunately, simply that of estimating total expenditures for the activity in question, then dividing the expenditure by the areal extent of the wetlands type providing the amenity value of social output. Thus net values of the expenditures are imputed to the wetlands, and there is no distinction between average and marginal social product. This is tantamount to a single factor theory of value, though the figures are offered as a surrogate for the estimation of the true social surplus values. Jaworski and Raphael have none of the evangelical zeal of Pope and Gosselink ([8]) in espousing this interpretation of the data; this is the best they could do at the time.

A great deal of effort was needed for the estimation of the various types of per acre benefit values. To calculate the per acre value of the duck habitat, they first estimated the areal extent of waterfowl habitat by types (spring migration or fall migration) and geographic locale. Then Jaworski and Raphael estimated the average physical product of the existing total migratory waterfall habitat. The numerous detailed areal extent estimates require a good deal of expertise in applied geography (in fact, Jaworski and Raphael were members of the Geography-Geology Department of Eastern Michigan University when they wrote this monograph).

A 1972 inventory estimated the areal extent of Michigan's coastal wetlands to be 105,855 acres (165.4 square miles). These coastal wetlands produced 21% of the waterfowl harvest, 14% of the duck production, 11% of the muskrat harvest, and 15% (by value) of the commercial fisheries harvest for Michigan. The sum of the average per acre commercial harvest and the total per acre expenditures for recreational activities is $489.69 per acre per year. The total value of

these commercial harvests and expenditures is about $51.8 million in mid-1970 dollars (Jaworski and Raphael spent little effort in adjusting for inflation).

For the various types of economic activities, the per acre expenditure values used to calculate the summary value are: (1) $286 per acre per year for sport fishing, (2) $134 per acre per year for nonconsumptive recreation activities, and (3) $31 per acre per year for migratory waterfowl hunting. Two commercial harvest values lie behind the summary value, $30 per acre per year for furbearing mammals and $3.78 per acre per year for the commercial fish harvest.

The inclusion of the per acre annual tertiary treatment benefits might have boosted the summary value of the total output estimate to over $3,000. However, the inclusion of the tertiary benefits value would be equivalent to adding apples and oranges, since it would presumably be a net benefits value, not a gross expenditure figure or receipts estimate. Also, the tertiary activity and the other activities are substitutes in production.

27. Johnson, R.L. 1978. Timber harvests from wetlands. Pages 598-605 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetlands functions and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal agencies and the American Water Resources Association, Minneapolis, MN.

Johnson defines wetland forests as those that occur in river bottoms and are subject to periodic flooding, or as those that are in bogs or swamps where the water table is near or above the land surface. The discussion is limited to commercial forests and timber stands. There are about 82 million acres of commercial wetland forests in the contiguous 48 States of the U.S. Three-fourths of the acreage is east of the Rockies, and two-thirds supports deciduous species. The most extensive and commercially significant stands occur in what may be called the oak-gum-cypress (30 million acres) forest type and the elm-ash-cottonwood (25 million acres) forest type. Little is known at present about these two forest types in the Northeast.

In the Southeast, these forest types are found under four distinct types of conditions: (1) well-drained stream margins, (2) swamps, bays, and wet pocosins (large, poorly drained depressions that often have peat soils), (3) flatwoods and dry pocosins (both terms describe large, level, sandy areas that are wet in winter and dry from late spring to fall), and (4) cypress ponds and river channels. Johnson estimates the average stumpage value of an acre of wetland forest to be about $250. Thus the value of the 32 million acres of Southern wetland forest has a total stumpage value of $8 billion (1978 dollars). However, dollar yields vary sharply with harvest costs and the quality of the timber stands. In deep swamps, even high quality stands have little value; high quality stands with desirable species in shallow swamps could be worth $1,500 per thousand board feet of stumpage. In 1978 prices, the best stands are increasing in value at the rate of $50.00 per acre per annum from growth in merchantable volume.

28. Lugo, A.E., and M.M. Brinson. 1978. Calculations of the value of saltwater wetlands. Pages 120-130 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetlands functions and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal agencies and the American Water Resources Association, Minneapolis, MN.

Lugo and Brinson strongly advocate a variant of the ecosystem life support function or energy theory of value introduced by Gosselink, Odum, and Pope (see [9]) and Pope and Gosselink ([8]) to impute dollar values to wetlands preservation benefits. This variant may be called the energy quality equivalent theory. Lugo and Brinson argue that the energy quality theory of value corrects several obvious deficiencies in the original formulation of the ecosystem life support theory of value. The energy quality theory of value allows Lugo and Brinson to impute values for work performed by solar energy in producing outputs other than primary plant biomass. Thus the energy and work done by ocean tides can be given dollar values with this approach. Another plausible consequence of applying this more elaborate version of the energy theory of value is that forest stands that are no longer growing rapidly, but which have appreciable quantities of stored solar energy, can be valued relative to primary plant biomass production.

Roughly, the quality correction denotes a value upgrading of solar energy that is stored at slow rates over long periods of time in landscape forms and plant biomass. Unfortunately, the paper is not self-contained, in that the energy quality theory itself is developed in other research documents; this paper merely applies the theory.

29. Odum, E.P. 1978. The value of wetlands: a hierarchical approach. Pages 16-26 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetlands functions and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal Agencies and the American Water Resources Association, Minneapolis, MN.

The author reviews the social benefits provided by various wetlands functions, including the provision of wildlife habitat for various terrestrial and aquatic species, groundwater recharge, waste assimilation, water purification, and atmospheric stabilization. He suggests that there are three methods for valuing these outputs and functions. The first, the common denominator approach, involves the application of an energy theory of value--(this approach is also called the "ecosystem life support" method in the work of Pope and Gosselink (see [8]) and Gosselink, Odum, and Pope ([9])--to impute preservation values to these wetlands.

The second is similar to what might be called an expert systems approach. It involves the use of experts to scale and weigh the outputs and functions. The third involves economists determining the replacement cost of various alternative means of obtaining these functions and outputs from other resources.

30. Peters, D.S., D.W. Ahrenholz, and T.R. Rice. 1978. Harvest and value of wetland associated fish and shellfish. Pages 606-617 _in_ P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetland functions and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal agencies and the American Water Resources Association, Minneapolis, MN.

The areal extent of a forest is a limiting factor in the production of lumber or other wood products. The quantity of aquatic or wetland habitat may or may not be a limiting factor in the production of important finfish or shellfish species. Precise quantitative estimates of the social benefits conferred by wetlands habitat are very difficult to obtain, since no data on the marginal contribution of wetlands habitat to fisheries yields is available for many of the important target species and many of the important wetlands habitats.

Other important difficulties in assessing the social contribution of wetlands to fisheries production arise from problems of measuring habitat; areal extent of wetlands may not be the only useful measure of wetlands habitat, and other habitat variables (e.g., factors relating to ph, water temperature, and salinity in estuarine zones for anadromous species) may limit production even though there is an abundance of wetland areas for fisheries production. Moreover, some species make only marginal use of wetlands, while others are completely dependent on wetlands habitat for completion of the life cycle. All freshwater fishing is considered to be wetland dependent, but not all saltwater fishing.

Wetland-associated species include marine, anadromous, and freshwater species. The authors of this paper include seven species in the freshwater group, including sunfishes, buffalo, catfishes, perches, and trout. Salmon, striped bass, shad, and alewife compose the anadromous group. Saltwater species include 13 finfish and shellfish groups, including bluefish, drum, fluke, seatrout, menhaden, mullet, blue crab, oysters, and shrimp. The total ex-vessel value of the 1976 commercial harvest of wetland-associated finfish and shellfish species was $700 million. The volume of the 1976 landings is not reported in the paper, but in 1974 the total menhaden harvest for the Nation was 1.35 million tons, while the total commercial harvest of all other estuarine wetland-dependent species (finfishes plus shellfish) was 1,127 million pounds. The areal extent of estuarine wetland habitat was 15,800 square miles. The catch per unit of estuarine habitat varied from a regional low value of 170 pounds per acre for the south Atlantic states, to a high of 1,253 pounds per acre for New England.

The paper also offers some fascinating data on the volume and value of recreational fishing. The number of freshwater angler participation days increased steadily during the 1955-1975 period. In 1955, there were 339 million angler days; in 1975, there were 1,275 million angler days. The percentage increase in saltwater angling participation levels (412%) was even greater than the 376% increase recorded for freshwater angling participation levels during this 20-year interval. In 1955, there were 59 million saltwater angling days; by 1975, there were 243 million angling days. However, Peters et al. indicate that the data may not be comparable for the entire period due to shifts in the extent of coverage for the 1975 data. Also, the data underestimate the economic significance of saltwater recreational fishing because recreational shellfishing

(clamming, crabbing, and shell collecting)--which totaled 220 million participation days in 1975--was excluded.

Total expenditures on recreational fishing were $15.2 billion in 1975. This is a poor measure of net social benefits conferred by the fish or the wetlands habitat, but it is a good barometer of (changes in) the number of jobs supported by recreation purchases. The willingness-to-sell an angling day minus the cost of an angling day is one useful measure of the benefits conferred by the activity. In 1971, the average willingness-to-sell a saltwater angling day was $74.47; the average cost for an angling day was only $10.77.

31. Shabman, L.A., and S.S. Batie. 1978. Economic value of natural coastal wetlands: a critique. Coastal Zone Management Journal 4(3):231-246.

The authors give an excellent critique of the work of Gosselink, Odum, and Pope (see reference [9]) and Pope and Gosselink (reference [7]) on imputing values to the preservation benefits of tidal marshes. The ecosystem life support system function performed by wetlands really invokes an energy theory of value. Single-factor theories of value have been used by various economists. Perhaps the most famous of these is Marx's labor theory of value in which the value of various goods and services is determined by the labor content of the commodity. Fixed coefficient, closed, linear activity models with a single factor input have been analyzed in detail to show the existence of a set of equilibrium prices that clear every market. However, the purpose of these complicated demonstrations is didactic; they show the remarkable power of the price mechanism to effectively allocate resources in the absence of any relation between the quantity supplied and the marginal social cost of producing goods and services.

Shabman and Batie point out that the appropriate technique for estimating wetlands preservation benefits is to estimate the net producer and consumer surplus for each and every wetland function and then estimate the net aggregate social surplus from the ensemble of values attached to the individual functions. The aggregate social surplus will not necessarily be a simple additive, linear function of the social surplus of the individual functions. There are some important omissions from the Shabman-Batie critique. There are really two single-factor theories of value presented in the work of Gosselink, Odum, and Pope. When Gosselink, Odum, and Pope impute the entire value of the commercial harvest of some species to the marsh, they are really using a land theory (more precisely, an areal-extent-of-land-surface) of value. The inconsistency in the two theories is neatly resolved; Gosselink, Odum, and Pope ([9]) and Pope and Gosselink ([8]) favor the theory that gives the highest preservation benefits. The really important flaw in the Shabman-Batie critique is that it takes no cognizance of the work of Gosselink, Odum, and Pope as rhetoric. Many economic arguments are rhetorical. The rhetoric is usually not aimed at first year graduate students in economics. As a piece of persuasive rhetoric, the single-factor theories used to impute wetlands preservations benefits have some strengths, but they also have some weaknesses. For example, it is impossible to consistently discuss the loss of environmentally sound jobs from the diminishing commercial harvests that are contingent on the existence of wetland habitat if all of the value of the commercial harvest is imputed to the wetland and none is imputed to the labor input.

32. Schamberger, M.L., C. Short, and A. Farmer. 1978. Evaluation of wetlands as wildlife habitat. Pages 74-84 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetlands, functions, and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal agencies and the American Water Resources Association, Minneapolis, MN.

Recent Federal legislation has charged the U.S. Fish and Wildlife Service with responsibility for evaluating wildlife habitat, including the Wetlands Acquisition Act, the Migratory Bird Treaty Act, the Endangered Species Act, the National Environmental Policy Act, the Fish and Wildlife Coordination Act, and the Watershed Protection and Flood Prevention Act. This legislative mandate assumes that reliable methods for evaluating habitat exist for describing unfavorable impacts of development on wildlife habitat.

Schamberger et al. describe the Habitat Evaluation Procedures (HEP), a methodology developed by the Service for evaluating baseline and postdevelopment or postmanagement conditions of habitat for various habitat types, including wetlands habitat. The basic assumptions underlying the methodology are that habitat value can be quantified, that habitat suitability for all animal species can be objectively determined and quantified, that habitat values can be determined by assessing the suitability of the habitat for a given species, and that habitat quantity and quality is a determinant of the number of animals in a given habitat (area). The Habitat Evaluation Procedures can be used to inventory baseline conditions, list habitat impacts of various management options and alternatives, evaluate alternative sites, and determine mitigation requirements for lost habitat. The economic implications of HEP have begun to be explored by the U.S. Fish and Wildlife Service through the development of the Habitat Management Evaluation Model (HMEM). This model can incorporate budgetary and cost considerations in a computational format that allows resource managers to assess the cost effectiveness of various habitat management alternatives.

33. Weller, M.W. 1978. Wetland habitats. Pages 210-234 in P.E. Greeson, J.R. Clark, and J.E. Clark, eds. Wetlands functions and values: the state of our understanding. Proceedings of a national symposium on wetlands. Various Federal agencies and the American Water Resources Association, Minneapolis, MN.

The author does an excellent job of summarizing recent research results on several subtopics under the general subject heading of wetland provision of wildlife habitat. These topics include wetland formation and biotic communities, the vegetative structures of wetlands, wetland habitat selection by animals, classification of wildlife wetland habitats, the dynamics of wetland habitats, and the wildlife impacts of wetland losses. The most interesting parts of the paper deal with some important management issues, namely, restoration of wetland habitat and management of wetlands for improvement in wildlife habitat. Natural management improvement practices include water level and fire management and control of herbivores. Artificial management techniques include the use of bulldozers, artificial nest sites, vegetation management, and blasting. A critical issue in wetlands restoration efforts is the control of exotic plants.

Weller suggests that much applied research is needed before biologists and other scientists have an adequate grasp of the best approaches to use in a given situation with regard to wetland restoration or augmentation of wetland habitat. Research should be directed toward developing rapid wetland habitat evaluation techniques, knowledge of wetland plant associations and plant growth rates (for use in wetland restoration efforts), and long-term biotic community dynamics. The paper obviously is a good starting point for the introduction of a wide variety of cost and benefit data in the development of cost effective wetlands habitat valuation techniques, though clearly a sustained, creative, research effort is needed before economists learn how to value the panoply of habitat provision benefits discussed in this paper.

34. Clark, J.R. 1979. Mitigation and grassroots conservation of wetlands-urban issues. Pages 141-151 in The American Fisheries Society mitigation symposium [Held in Fort Collins in 1979]. American Fisheries Society, Bethesda, MD.

The author considers the difficulties of mitigating coastal wetlands loss in the greater metropolitan New York and Los Angeles areas. Wetland preservation benefits are high in these two regions, as are the potential returns to development activities. This leads to protracted political and administrative conflict over land use.

35. Crites, R.W. 1979. Economics of aquatic treatment systems. Pages 475-485 in EPA aquaculture systems for wastewater treatment symposium. EPA 430/9-80-006. U.S. Environmental Protection Agency, Office of Water Program Operations, Washington, DC. [Can also be obtained on request by writing the consulting firm of Metcalf and Eddy, Sacramento, California.]

The author reports that aquatic wastewater treatments are very cost effective relative to the conventional chemical and land-based systems. Aquatic systems include artificial wetlands, macrophytes (principally water hyacinths), invertebrate-based systems, finfish systems, and integrated polyculture systems that use various aquatic plants and animals as treatment components. The artificial wetland system has low costs relative to conventional methods, but the author suggests that they are not as efficient as natural wetland systems.

36. Hoffman, D. 1979. Wetland$ . . . for value received. Ontario Naturalist 19(2):35-37.

The author gives a brief, useful history of wetland drainage activity in the Canadian Province of Ontario. Many of the wetlands of southern Ontario have been drained and filled, often for agricultural use. However, extensive peat bogs remain in northern Ontario. The peat bogs offer a fascinating example of the need for regulatory activity to preserve the benefits conferred by the wetlands. Certain private activities that tend to deplete the resource base currently use wetland resources as a highly productive factor input. Cultivation and drainage activity in Ontario's Holland Marsh (the market garden center of Canada) are depleting the agriculturally productive peat bog layer 1-2 inches per year. Eventually this peat layer--whose current average depth is 23 feet--will disappear. A conventional assessment of the panoply of wetland amenity values is sketched in the introduction.

37. Shabman, L., and M.K. Bertelson. 1979. The use of development value estimates for coastal wetland permits decisions. Land Economics 55(2):213-222.

The authors develop techniques and equations for quantifying wetland development values. The approach is essentially the same as that developed in Abdalla and Libby ([58]). A simple hedonic equation is developed for relating the transfer price of a lot as a function of the value of improvement expenditures, lot size, the year of the sale, and waterfront amenity characteristics of the lot. Thus if P is the transfer price, W represents the waterfront amenities value, Y represents the year of the sale, X is a vector of qualitative variables (that represent the impact of the neighborhood in which the lot is located), and A is the lot size, then the estimated equation is

$$V = K + b_1 A + b_2 V + b_3 Y + a_1 X_1 + a_2 X_2 +$$

$$a_3 X_3 + a_4 X_4 + b_4 W + b_5 W^2 + b_6 (Y W^2).$$

There are some differences between this equation and the equation estimated by Abdalla and Libby. The waterfront variable in the work of Shabman and Bertelson is represented by an index that combines several variables (including water frontage in feet, and a dummy to indicate whether the land parcel was on a natural bay or manmade channel), while the separate variables are used as independent dummy or quantitative variables in the work of Abdalla and Libby. Also, the dependent variable in the work of Shabman and Bertelson is not the recorded transfer price, which is the present value of a set of annual income payments, but the size of the annual income payments. In the equation estimated by Abdalla and Libby ([58]), it is the actual transfer price. Abdalla and Libby discuss Michigan wetlands, while the wetlands discussed in the work of Shabman and Bertelson are Virginia coastal wetlands. The social opportunity cost of preserving the "undeveloped" waterfront is partially captured through the coefficient of the amenity variable, since it quantifies the contribution of the wetland to the increase in the transfer price. However, as Abdalla and Libby ([58]) point out, there is a presumption that no other site has similar (though lesser amenity value) that would also enhance the value of improvement expenditures. Thus the equation represents an approximation to a more complicated situation.

Shabman and Bertelson do not make the mistake of asserting that the coefficient of the waterfront amenity value captures the development benefits of the wetland. Without the wetland, there are no waterfront amenities, so one of the preservation benefits of the wetland is enhanced real estate values for all waterfront lots. There is a difference between the preservation benefits of the completely undeveloped wetlands, and the preservation benefits of the open space and water that remains after the strip around the wetlands has been used for real estate development. The larger the open space and the more water it contains, and the more variegated (e.g., islands with hillocks might be located within the undeveloped interior of the island) the landscape, the higher the real estate value of the waterfront lots.

Hence, enhanced real estate values may be one of the preservation benefits provided by a wetlands. However, this preservation benefit is somewhat more

abstract than the Shabman-Bertelson paper suggests. Houses located a block or more from a wetlands can have a greatly enhanced real estate value from their proximity to the wetland, if all of the lots in the area are large, even if the lots are all a block or more from the wetland. The range of physical characteristics over which realty development and wetlands preservations benefits are substitutes for each other needs to be defined more carefully.

38. Thomas, M., B. Liu, and A. Randall. 1979. Economic aspects of wildlife habitat and wetlands. Midwest Research Institute and Water Resources Council, Kansas City, MO. 88 pp.

This is a comprehensive treatment of the conceptual and empirical problems that arise in valuing wetlands habitat outputs. Perhaps the major contribution of the monograph is that it forcefully demonstrates the path-breaking nature of the work of Hammack and Brown (see [10]). It reviews the work of biologists in quantifying the habitat versus recruitment class relation, and the complex interaction between habitat values and socially desirable environmental attributes. Thomas, Liu, and Randall point out that estimation of the marginal value product of wildlife habitat is difficult due to the provision of joint products. Thus wildlife observation and sport hunting are, to some extent, joint products that are supplied by wildlife habitat.

Other difficulties in estimating the marginal physical productivity relation include multiple habitats (breeding, overwintering, and migratory habitats), habitat heterogeneity, and habitat indivisibility. The last named identification problem stems from the use of multiple habitats by certain species; it is the difficulty in distinguishing the particular contribution of one of several types of habitat that are needed by the species to complete the life cycle.

39. Beal, K.L. 1980. Territorial sea fishes management and estuarine dependence. Pages 67-77 in V.S. Kennedy, ed. Estuarine perspectives: proceedings of the fifth biennial international estuarine research conference. Academic Press, New York.

The article points out that estuarine zones and saltwater coastal marshes and swamps are essential habitat for a number of economically important finfish species. Beal believes that there is little data on the value and volume of the commercial catch for shallow Atlantic saltwater fisheries (see, however, the important paper by Peters, Ahrenholz, and Rice [30] for presentation and interpretation of data on the volume and value of the wetland dependent finfish and shellfish catches). Beal asserts that the value of the recreation catch of certain target species is greater than the value of the commercial catch. He believes that regulation of marine fisheries to prevent heavy overfishing is needed to preserve these precious resources.

40. Owens, R.E., III. 1980. The economic value of Virginia's coastal wetlands as an erosion control device. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 130 pp.

The author analyzes data that show that wetlands erode as rapidly as fastlands on the Virginia shores of the Chesapeake Bay, but wetlands do impede

erosion of the fastlands that lie behind the shoreline wetlands. Owens imputes a dollar value to this buffering function, but the same buffering benefit could be provided by artificial wetlands, or through some artificial tidal wave barrier.

41. Schamberger, M.L., and H.E. Kumpf. 1980. Wetlands and wildlife values: a practical field approach to quantifying habitat values. Pages 37-46 in V.S. Kennedy, ed. Estuarine perspectives: proceedings of the fifth international biennial estuarine research conference. Academic Press, New York.

This paper reviews a method for quantifying development impacts and baseline conditions for wildlife (aquatic and terrestrial) habitat; much of the recent conservationist legislation assumes that such a methodology exists. This particular method was developed by the U.S. Fish and Wildlife Service and is called the Habitat Evaluation Procedures (HEP). The HEP method involves using habitat suitability indices for relevant species to derive habitat units for wildlife management sites for various target species. The habitat units are the product of the areal extent of the site in acres and the habitat suitability index (a nonnegative number less than or equal to one) for each particular species. However, aggregation of habitat units over species is also feasible. The authors provide an example that illustrates the quantification of baseline habitat conditions for a wetland by aggregating over habitat units for multiple target species. The aggregation procedure is appropriate if the wildlife managers are willing to use certain mitigation techniques.

The economic implications of HEP were further developed by the U.S. Fish and Wildlife Service by the integration of budget constraints and cost considerations in the Habitat Management Evaluation Model (HMEM).

42. Shabman, L.A., and S.S. Batie. 1980. Estimating the economic value of coastal wetlands: conceptual issues and research needs. Pages 3-15 in V.S. Kennedy, ed. Estuarine perspectives: proceedings of the fifth biennial international estuarine research conference. Academic Press, New York.

The underlying theme of the paper is that society needs to protect estuarine wetlands even though the best available evidence suggests that there are no remarkably large nonmarket benefits provided by these wetlands. They argue that society might have to face the fact that these landforms need to be protected on rationale and criteria similar to those underlying the Endangered Species Act. Estuarine wetlands are beautiful and exciting natural wonders, and the human race would be poorer in spirit and imagination--though perhaps not materially--if these wetlands were lost. The authors assess the problem of imputing economic values to the following beneficial wetland functions: (1) flood control, (2) erosion control, (3) provision of oyster habitat, (4) provision of waterfowl habitat, and (5) waste treatment.

Shabman and Batie believe that the most obvious common feature of these alleged functions is that it is currently difficult to impute firm dollar values to the social net benefits conferred by them individually and collectively. Therefore, the case for attaching high preservation benefits to these wetlands

is flimsy. Conversely, they believe that our poor grasp of the biological, hydrological, and chemical functions performed by estuarine wetlands suggests that most development permits for coastal wetlands development projects should be denied. Shabman and Batie think that this is the prudent course of action for a society composed of enlightened risk averters.

43. Balco, J.J. 1981. Assessing wetlands values--evaluation dilemmas. Pages 421-429 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, St. Paul.

In 1979, the U.S. Water Resources Council sponsored a series of workshops on "Emerging Issues in Wetlands/Floodplain Management." The Council decided that before embarking on a program of developing new specific methodologies a thorough analysis of existing methodologies would be useful. This insight led to the formation of an interagency task force to oversee the analysis. The task force decided that five functional values should be considered in a wetland evaluation methodology, including habitat provision, hydrologic benefits, recreation benefits, agricultural uses, and the national or global cultural heritage transmitted through wetlands. Roughly, the findings of the task force were that no general methodology for assessing all wetlands functions was available; many useful methodologies were available for assessing habitat provision; and few, if any, adequate methodologies were available for assessing recreational benefits, agricultural benefits. or hydrologic functions performed by wetlands. In view of the sophisticated analytic economic tools available to impute site-specific recreation benefits, this finding (that there is no good methodology available for assessing wetland recreation benefits) suggests that the task force needed much more input from natural resource economists.

44. Bardecki, M.J. 1981. Wetlands in southern Ontario: a policy science approach. Ph.D. Thesis. York University, Ontario, Canada. 275 pp.

Bardecki examines the causes of wetland conversion in southern Ontario. Farmland conversions are the principal cause of wetlands loss in this region. The author recommends abandonment of the wetlands conversion subsidization program of the Federal Government. (This thesis was published in 1984 as Geographical Monograph No. 16 by York University.)

45. Jaworski, E., and C.N. Raphael. 1981. Results of wetlands value study in Michigan. Pages 445-451 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, St. Paul.

The same technique, data, and values that were reported for the preservation benefits of Michigan coastal wetlands in an earlier study (see [26]) by the authors are reported here. In addition, Jaworski and Raphael develop replacement costs for the same wetlands for various specific wetland functions. The defect with the estimation technique is that it imputes all of the value of the estimated expenditures (if the function is provision of outdoor recreation activity) or the entire value of the harvest (if the function is provision of habitat for a commercially harvested wildlife species) to the wetlands. A conventional value of a participation day for the activity in question as

estimated by the U.S. Fish and Wildlife Service was then added to the per acre expenditure values. The estimated annual returns from that earlier study were $426 per acre for provision of habitat for fish that were caught by sport fishermen; $418 per acre for provision of nonconsumptive outdoor recreation sites; $42 per acre for waterfowl habitat provision for bagged waterfowl; $30 per acre for habitat provision for fur-bearing species; and $5 per acre for provision of habitat for commercial fish species. The total value for all functions is $651.

The annual replacement cost calculations are not given in detail, but the authors state that they incorporate a capital cost and adjustments for the rate of inflation. Basically, the procedure involves simply adding together amortized capital costs and annual operating costs and subtracting the net cost of land ownership. Two replacement cost figures for most functions are listed, one for purchased replacement and one for constructed replacement. The annual purchased replacement value for fish production was $1,040 per acre; for waterfowl habitat it was $720 per acre; and for water supply it was $16--the purchased replacement cost and the constructed replacement cost were the same for water supply.

46. Leitch, J.A. 1981a. The wetlands and drainage controversy revisited. Minnesota Agricultural Economist, No. 628, St. Paul. 5 pp.

This is a condensed introduction to the economics of wetland drainage, the wetlands classification system, and changing social attitudes toward amenity values provided by wetlands. The paper focuses on the prairie pothole wetlands in the northern central Great Plains region. The U.S. Fish and Wildlife Service's wetland classification system recognizes four inland freshwater wetland types that commonly occur in the prairie plains. These include the type 1 (seasonally flooded basins or flats), 3 (inland shallow freshwater marshes), 4 (inland deep marshes), and 5 (inland open freshwater wetlands) wetlands types. All Federal subsidies for the drainage of type 3, 4, and 5 wetlands were discontinued in 1962. Other on-farm wetlands drainage was subsidized by ASCS (the Agricultural Soil Conservation Service of the U.S. Department of Agriculture) through 1977.

In 1981, a number of programs offered incentives to farmers to preserve wetlands, including the fee title and easement purchase programs of the U.S. Fish and Wildlife Service, the ASCS Water Bank, the Minnesota Water Bank, the Minnesota Wetlands Tax Credit Program, and State and Federal regulatory restrictions on drainage. Many of the programs, including the Federal programs listed above, are still viable. Under the U.S. Fish and Wildlife Service's easement program, the farmer is paid a single lump-sum payment to agree to not fill, drain, burn, or level his on-farm wetlands. The landowner retains ownership and pays the real estate taxes; the life of the contract is usually 99 years, though 30 year and 50 year contracts exist. Under the fee title purchase program of the Service, the Federal Government makes an outright purchase of the wetland acreage (and it usually purchases an adjacent parcel of upland acreage that is at least as large as the wetland). Much of the fee title lands purchased by the U.S. Fish and Wildlife Service are classified as waterfowl production areas.

Leitch lists a large number of beneficial functions performed by wetlands. These include provision of natural firebreaks, expediting the global cycling of nitrogen and sulfur, historical value, forestry products, shoreline protection, erosion control, endangered species habitat, wildlife habitat, primary productivity, flood control, and groundwater recharge.

The wetland allocation problem is usually described as the problem of selecting the socially optimal wetland acreage that should be preserved, given the social constraint that drained wetlands provide sizeable market returns, but wetland acreage provides socially significant nonmarket benefits. This raises two problems: (1) determining the socially optimal wetland acreage, and (2) devising regulatory mechanisms that preserve the desired wetland acreage. As Leitch points out, this national perspective ignores certain complexities. Namely, the regional rural economies in which the wetlands exist gain tax receipts and augmented regional expenditure flows as wetlands are drained; they lose tax receipts and regional income as more wetlands are preserved.

47. Leitch, J.A. 1981b. Valuation of prairie wetlands. Ph.D. Thesis. University of Minnesota, Minneapolis. 188 pp.

Leitch discusses the wetlands of the Atlantic and Gulf of Mexico coasts, inland Massachusetts, the Lake Michigan coastal wetlands of the State of Michigan, and the coastal marshes of Virginia, as well as the prairie pothole wetlands of the great plains. The author believes that he has shown that average wetlands values tend to approximate marginal values. This implies that the marginal values of wetlands preservation benefits are almost always positive because total preservation benefits for many wetlands functions are sizeable. Moreover, Leitch argues that the prairie potholes wetlands of the northern plains of the U.S. and southern Canada can be restored after drainage. Again, this simplifies the benefits estimation problem considerably because the irreversibility constraint on social investment might complicate the problem of selecting the optimal stock of social capital (wetland acreage).

The bulk of Minnesota farmers who have drained on-farm wetlands enjoyed a positive return on their investment, although some farmers undertook investment in drainage even though they anticipated low pecuniary returns. For these operators, drainage had a high nuisance removal value. Leitch does not actually provide empirical estimates of the values of various wetlands functions in this work.

48. Leitch, J.A. 1981c. Prairie wetlands allocation: an overview of landowner alternatives and regional impacts. Pages 467-477 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, St. Paul.

Leitch states that for farms in west-central Minnesota the net present value of the return on random ditch drainage in 1981 was \$141 per acre; on random subsurface tile drainage the net annual return was \$83 per acre; on general field drainage investment in south-central Minnesota it was \$630 per acre. The terms "random" and "general field" that are used to describe drainage layouts distinguish between the presence or absence of an orderly geometric pattern to the tile lines or drainage ditches. In "random" or randomly selected layouts,

tile lines run in any and all directions in an effort to provide each of a group of isolated wet spots with its own drainage outlet. In general field drainage, large continuous field areas are drained, and subsurface tile lines and ditches are usually laid out in a neat geometric pattern. The per acre cost of installing the drainage equipment varied considerably. It was $143 per acre for ditch drainage in west-central Minnesota, $514 per acre for subsurface tile drainage in west-central Minnesota, and $374 per acre for general field drainage in south-central Minnesota. All net return and cost data are for 1981, in 1980 dollars.

Thus despite the fact that the Federal Government dismantled all direct subsidization of on-farm wetland drainage by farmers in 1977, the incentive to drain remains high. Moreover, Federal regional flood control investment programs are an important indirect means of subsidizing private on-farm investment activity.

There are a number of factors to be considered in comparing the private and public (regional) returns to enrolling wetland acreage in the U.S. Fish and Wildlife Service's easement payment program with the public and private returns to drainage. Leitch considers some of these factors. One consideration is the nonpecuniary returns to drainage investment. Leitch estimates that the value of estimating a nuisance wetland may be $30-$60 per acre per year. He also cites lack of information (the cost of obtaining information) about the benefits of wetlands preservation programs as a factor generating drainage activity in Minnesota.

Still another factor to be considered is the effect on regional incomes and employment of withdrawing an acre of drained wetland from crop production and enrolling it in one of the preservation programs. Leitch asserts that there is a net gain in regional employment and incomes from enrolling west-central Minnesota wetland acreage in one of the preservation programs. The income received from the payments is more likely to be spent locally than would a similar sum received as crop payments. The structure of the regional economy for this part of Minnesota plays a part in the net regional impact. In Minnesota, the economy is structured for both agriculture and tourism. In a more predominantly agricultural region, such as North Dakota, there might be a slight net loss of regional jobs and income.

Leitch's study assumed that there only 1% of the land was controlled by the U.S. Fish and Wildlife Service. If a larger fraction of land were controlled by the Service, there might be a net loss of jobs and income from enrolling a marginal acre in the preservation program. Another regional economic factor to be considered is the potential loss of property tax revenues. Leitch cites a recent study in west central Minnesota that indicates that counties did not lose (total) tax revenues, although some individual tax districts did lose total tax revenues.

49. Leitch, J.A., in collaboration with L. Falk, W.C. Nelson, L.A. Ogaard, and D.F. Scott. 1981. Socioeconomic values of wetlands: concepts, research methods, and annotated bibliography. North Dakota State University Agriculture Experiment Station Research Report No. 81, Fargo. 42 pp.

The annotated bibliography in Leitch et al. is distinct from the extensive (129 citations) literature cited section appended to the main text of the paper. The annotated bibliography has six reference sections, including general wetlands literature, bibliographies, conference and symposia proceedings, wetland economics, recreational and wildlife literature, and natural resources literature. There are brief discussions of selected references in all of the various sections. There are 93 references in the wetlands economics literature; there is little or no attempt to avoid overlap in the references in this annotated bibliography and the 1977 annotated bibliography (reference [18]) by Leitch and Scott. The discussions are too terse to convey more than the subject matter of the references.

The main text of the paper deals primarily with the economics of wetlands allocations, though there is some discussion of the problem of estimating the sociological (perhaps community is a better term) values of wetlands preservation. There is a useful discussion of the problem of achieving the socially optimal allocation of wetlands resources. The principal difficulties in achieving this social optimum stem from market failure; the wetlands preservation benefits are not priced or provided in any market, while the private returns to private investment in drainage and filling of wetlands are often substantial.

The authors assume that the reader is well-acquainted with the economics underlying this policy issue. Leitch and Scott emphasize somewhat technical issues, such as the best methods for measuring the totality of market benefits of wetland drainage and the nonmarket wetlands preservation benefits. The most original contribution is an interesting discussion of the role of an input-output model in identifying and measuring regional impacts of wetland allocations.

50. Leitch, J.A., and D. Kerestes. 1981. Agricultural land drainage costs and returns in Minnesota. Department of Agricultural and Applied Economics Staff Paper No. P81-15, University of Minnesota, Minneapolis. 58 pp.

Most of the economic substance and policy implications of the research reported in this paper was reported in a paper by Leitch ([48]). However, the paper by Leitch and Kerestes reports significant details of the research that are omitted in the other work. The authors studied the costs of drainage and the net returns of drainage for two regions in Minnesota. These are south-central Minnesota, and west-central Minnesota. Numerous differences in the historical drainage pattern exist between the two regions; and much of the value of the paper stems from the listing of these and other significant details. For example, 2.3% of the area in the west-central region is enrolled in wetland preservation programs, but only 0.3% of the area in the south-central region is enrolled in wetland preservation programs. Very roughly, about 20%-60% of the cropland in the west-central region has been drained; about 60% of the land in the south-central region has been drained.

One important stimulus to the research reported in the paper is the paucity of data on drainage costs. Goldstein (1967; An economic analysis of the wetlands problem in Minnesota; Ph.D. Thesis, University of Minnesota) estimated the cost of tile drainage to be $157 per acre, and $50 per acre for ditch drainage (1963 dollars) for two Minnesota regions. These estimates were based on 1967 data.

The data on costs in the paper by Leitch and Kerestes were categorized by region and drainage type. Random ditch and random tile drainage costs were reported for west-central Minnesota; for south-central Minnesota, general field drainage costs were listed. The authors used a 12% and 8% discount rate to calculate present values; the crop yield on a representative acre of composite cropland in each region was used to calculate gross returns to investment. Extra labor costs were computed for all cropping on all drained wetland acreage, but marginal machinery costs for the drained acreage were assumed to be zero. A before and after tax net return was calculated. Returns were calculated using a 15-year and 25-year life of investment, and under varying assumptions about maintenance expenditures. Thus the net present value of returns for drainage investment reported in ([48]) ($141 per acre for random ditch drainage, $83 per acre for random tile drainage, and $630 per acre for general field drainage) are before tax returns on 15-year investments that were calculated using a 12% discount rate.

51. Lynne, G.D., P. Conroy, and F.J. Prochaska. 1981. Economic valuation of marsh areas for marine production processes. Journal of Environmental Economics and Management 8:175-186.

Lynne, Conroy, and Prochaska calculate some of the wildlife habitat preservation benefits of coastal wetlands by estimating a two-factor production function for the Florida blue crab harvest. The habitat, or environmental amenity input, is quantified by the areal extent of wetlands. The time series data for the areal extent of wetlands were established by aerial photographs. The other factor input for this production function was human effort. The effort variable was quantified by the average annual number of traps used in harvesting Florida blue crabs. The dynamic econometric model is based on the Verhulst (logistic) dynamic population growth equation.

The model was estimated by ordinary least squares (OLS) regression techniques for a dynamic reduced form equation:

$$C_t = c_o + c_1 X_1 - c_2 X_2 + c_3 C_{t-1} + e_t.$$

The use of the lagged value of the dependent variable "dynamizes" the equation; C_t, the harvest in year t, is the dependent variable, while the harvest lagged one period (C_{t-1}) is an independent variable. The other two independent variables represent interactive terms that are the product of the natural logarithm of marsh acreage ($\ln M_t$), and E_t, the effort variable, in the case of X_1, and the product of ($\ln M_t$) and $(E_t)^2$ in the case of X_2. The randomly distributed error term is e_t.

The equation was estimated from data covering the 1952-1974 period. Photos for the various marsh areas were available for 3-6 years of the 23-year period; linear interpolation was used to establish the values of marsh acreage for other years. To establish the value estimates, a marsh was defined technically as a small bay or estuarine area less than or equal to 1.5 miles in width where the saltwater table is at or above the land surface and river inlets up to the tree lines. The effort variable was quantified by the average number of blue crab traps used during the year. The overall R^2 of the estimated equation was 0.78; the Durbin-Watson statistic was 2.05, indicating the absence of autocorrelation

among the residuals. Omitting the lagged value of the catch variable from the equation lowered the overall R^2 only marginally, but it had a significant impact on the t-values of the other independent variables. The marginal value product of effort was positive and decreasing (as a function of the number of traps) until E reached 50,000 traps. Similarly, if E was less than 49,800 traps, the marginal product of marsh was positive and a monotone decreasing function of the marsh acreage.

The estimated marginal product of marsh acreage was 2.3 pounds of blue crab per acre per year at the mean level of effort; the (dockside) marginal value product was between $0.25-$0.30 (the year used to index the prices is not reported). The per acre capitalized preservation benefits for habitat provision for blue crab are on the low side; depending on the discount rate, they are in the $3-$10 range if the discount rate is in the 3%-10% range. The Florida blue crab fishery was chosen for the estimation of habitat provision benefits by coastal marshes because of the emerging issue of preservation versus inundation of the marshes, and because the blue crab migrations made it easier to relate yields to marsh areas. The work of Farber and Costanza (see [79]) on the brown and white shrimp fisheries of Louisiana suggests that the low price of blue crab is one factor underlying the low estimated preservations benefits.

52. Mustard, E.W., and G. Loomis. 1981. Wetland versus agricultural lands: perspectives on values and trade-offs. Pages 441-449 in Walter F. Juske, ed. Economics, ethics, ecology: roots of productive conservation. The Soil Conservation Society of America, Aukeny, IA.

This paper presents no formal economic analysis. It does take a challenging, if somewhat oblique, look at an interesting issue--landscape planning for the present and future optimal social use of the land base resource of North America. The American public needs to develop an ethic in which viable landscape planning is deemed to be compatible with its free market ethic. Otherwise, it is pretty clear that economists' estimates of wetlands preservations benefits will have little effect on the real world allocation of resources. Mustard and Loomis are sanguine about the prospects of a meaningful integration of a landscape planning perspective into the fabric of American life.

53. Postel, S.L. 1981. The economic benefits of pocosin preservation. Pages 283-302 in C.J. Richarson, ed. Pocosin wetlands: an integrated analysis of coastal plain freshwater bogs in North Carolina. Hutchinson Ross Publishing Company, Stroudsberg, PA.

The term "pocosin" can be used to describe any wet area dominated by shrubs though it comes from an Algonquin Indian word meaning "bog on a hill." Thus some scientists might interpret the term to refer to raised bogs. However, any wet region that is heavily dominated by shrubs is called a pocosin. Pocosins may represent a seral stage or a climax plant community. Postel probably describes a variety of wetland types by the term; she uses the word pocosins to describe wetlands that affect the downstream quality of estuarine water, thereby affecting wildlife habitat for shrimp. She also uses the term to describe forested wetlands that provide wildlife habitat for black bears (forested bottomland hardwoods).

Postel divides the preservation benefits for the wetlands on the coastal plains of North Carolina into two categories: benefits that are quantifiable and benefits that are nonquantifiable. The distinction seems quaint in view of the widespread use of contingent value methods for quantifying the social benefits of a wide variety of public amenity values. Quantifiable benefits include hunting, the maintenance of estuarine water quality, flood control, and water supply. Nonquantifiable benefits include the maintenance of critical habitat for animal species such as black bear, alligators, cougars, and the pine barrens tree frog. Various threatened and endangered plant species are part of the ecosystems of these wetlands, including spring flowering goldenrod and whitewicky kalmia.

The quantification of the hunting benefits provided by the North Carolina Game Lands (which are predominantly composed of pocosins) was made from data on the number of hunting trips made to these lands during the 1977-78 season. Value estimates of the user-day consumer surplus were elicited from experts in the field (the Delphi technique) and used to calculate the aggregate consumer surplus. However, the author suggests that the imputed numbers are only illustrative. The present value estimates were capitalized by using a technique introduced by Fisher, Krutilla, and Cichetti (see [18] for a complete citation and further discussion) that incorporates projected growth in income and population to estimate the growth in per capita annual preservation benefits. However, the range of capitalized per-acre preservation benefits is quite wide; the low value is $8.92, the high value is $1,136.25, depending on the user-day consumer surplus value, the projected growth in aggregate net benefits, and the choice of discount rate.

The impact of pocosin drainage on estuarine water quality and contingent shrimp and finfish yields is problematic. The author presents a hypothetical case based on the existence of a strong relation--the more wetlands are drained, the poorer estuarine water quality and the lower shrimp yields--to illustrate the magnitude of the potential economic effects involved.

54. Shropshire, F.W. 1981. Land-use competition in wetlands. Pages 50-59 in 30th annual forestry symposium. Louisiana State University, Baton Rouge.

Shropshire makes a useful observation in noting that some uses of wetlands are limiting, others are not. By limiting, he means that certain wetland uses, even when pursued on a modest scale, preclude other wetland uses. Limiting uses include agriculture, surface mining, cattle grazing, homesites, and oil exploration and production. Nonlimiting uses include bee forage, sound barriers, bird watching, aesthetic benefits, wind breaks, air filters, and shoreline erosion protection. Some wetland uses, including wildlife habitat and recreational site provision, are limiting only if pursued on a sufficiently intensive scale. The author discusses the role of multiple-use land management techniques in achieving a rough social optimum in bottomland hardwood wetlands.

Shropshire lists the four social forces he believes to be foremost among those causing drainage and conversion of bottomland hardwood wetlands. These include the 1928 Flood Control act, expanding world population, rising demand for soybeans, and the relatively low stumpage value of bottomland hardwood

timber. The most easily overlooked is perhaps the Flood Control Act of 1928. The passage of the swampbuster provisions of the Food Security Act of 1985 imposes stiff sanctions on farmers who drain on-farm wetlands and attempt to participate in various Federal farm programs. The Federal Government has not directly subsidized farmland conversion of wetlands since 1977, but these two facts do not indicate a complete cessation of indirect Federal subsidization of on-farm wetland drainage. The 1928 Flood Control Act authorizes Federal expenditures for (on-going) river channelization projects that enhance the effectiveness of private on-farm drainage investment.

55. Stoecker, A., G.A. Mathia, H.T. Cardwell, and A. Knight. 1981. Economic considerations of playa lake enhancements for wildlife. Pages 112-122 in Playa lakes symposium proceedings. U.S. Fish and Wildlife Service, FWS/OBS-81/07. Washington, DC.

Playa lakes are relatively shallow depressions located in the high plains of Texas. Estimates of the number of playas range from a low figure of 17,000 to a high of 30,000. They are either periodically or permanently inundated by collected rainwater. Most playa lakes are periodically inundated due to high evaporation rates and irrigation pumping. As the high plains aquifers are mined and pumping costs rise, these small--1-200 acres in areal extent--bodies of standing waters are used more frequently and heavily to irrigate crops. They have some other agricultural uses, and these uses are not complementary with the socially beneficial nonmarket provision of habitat. Small playas are sometimes plowed for weed control or as cropland, though crop yields on former playa acreage are often low. Large areas are often modified and used for irrigation water reserves or for livestock grazing after drainage. The playas provide valuable nesting habitat for pheasant and overwintering migratory waterfowl. No data seem to be available for estimating the public benefits lost due to playa drainage. The authors suggest that government agencies engage in a playa easement purchase program to preserve wildlife habitat. They also suggest that these agencies facilitate the development of a leasing market in which hunters could lease playas and adjacent farm sites for hunting purposes.

56. Sutherland, J.C. 1981. Economic implications of using wetlands for wastewater treatment. Pages 295-305 in B. Richardson, ed. Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board, St. Paul.

Unfortunately, this paper has no economic analysis. It does contain very detailed data on the use of wetlands as wastewater treatment facilities. The data could be used to make detailed comparisons between the use of wetlands and other types of wastewater treatment approaches. More specifically, the costs are for using Michigan riverine wetlands for treatment of pond-stabilized municipal wastewaters from small, rural populations. The cost estimates were simulated by a model in 1976-77 and are updated in the present paper. The capital costs are closely approximated by the simple linear relation

$$C = 117D + 262$$

where C is the cost in thousands of dollars, and D is the distance from the ponds to the wetlands.

The Houghton Lake Sewer Authority added a natural State-owned peatland tertiary treatment system to its pond-seepage stabilization system facilities to serve 6,000 full-time and 14,000 seasonal residents. Capital costs for the system were $507,000; annual wetland operation and maintenance costs totaled about $19,000.

57. Thibodeau, F.R., and B.D. Ostro. 1981. An economic analysis of wetland protection. The Journal of Environmental Management 12:19-30.

This article estimates the economic values of the public benefits provided by the swamps and marshes of the Charles River basin in Massachusetts. The authors assess the hydrologic, aesthetic, and recreational benefits provided by these extensive woodlands. The Charles River basin woodlands encompass 8,535 acres of marsh and wooded swamp in Suffolk, Norfolk, and Middlesex Counties in Massachusetts; they compose three-fourths of all of the wetlands of Boston's major watershed.

The hydrologic functions performed by these woodlands include groundwater recharge, flood control and abatement, and contaminant removal. The authors estimate the capitalized value of the net social benefits provided by these three functions to be over $150,000 per acre. Most of the value is provided by the groundwater recharge function, however, and the groundwater recharge value does not refer to a function actually performed by the wetlands.

It is the maximal value that retrieval of the waters currently stored in the aquifer would yield if society sunk wells into the aquifer and pumped the waters at the recharge rate. However, the potential yield from the aquifer cannot be valued in the same manner as the actual yield.

The imputed values for other functions were developed from data and research provided by the U.S. Army Corps of Engineers (flood prevention estimates of $33,000 per acre for capitalized benefits) and the Environmental Protection Agency and a private consulting firm (contaminant removal estimates of $16,960 per acre for capitalized benefits). The discount rate used to capitalize annual per year benefits was 6% for the hydrologic functions (the discount rate used to capitalize annual recreation benefits flows was, however, 8.75%). Thibodeau and Ostro argue that the average value of the flood prevention function should be used in calculating the per acre flood prevention benefits because the wetlands are essentially an indivisible resource.

The capitalized values of the per acre recreational and aesthetic benefits lie between $2,145 per acre and $38,469 per acre. The lower number is based on aesthetic and recreational (hunting and fishing) benefits, while the higher number includes the estimated value of scientific study benefits. However, the disparity in the numbers also reflects different techniques used to estimate the recreational activity consumer surplus. For the smaller number, the recreation related consumer surplus loss is calculated with a "willingness-to-pay" consumer surplus estimate for a participation day; for the larger value, it is caLculated as the "willingness-to-sell" consumer surplus estimate for a participation day in the recreational activity. The various activities include small game hunting, waterfowl hunting, trout fishing, warmwater fishing, and nature study. The U.S. Fish and Wildlife Service supplied data on the number of participation days in

the study area, as well as national data on the willingness-to-sell and willingness-to-pay for the various activities.

The imputed summed value for the recreational activities is about 18 times greater using the willingness-to-sell concept than for the willingness-to-pay approach. However, the aggregate consumer surplus estimate using the willingness-to-pay approach is about twice as great as it would be using conventional methodology because it is usually calculated as willingness-to-pay above actual cash outlays; the expenditures are added to the willingness-to-pay values in the Thibodeau and Ostro estimates. This is a serious conceptual error, but it would have been mitigated had Ostro and Thibodeau pointed out the unorthodox nature of their procedure.

The aesthetic benefits are imputed through the estimation of hedonic (location related) real estate prices; the basic technique is highly similar to that employed by Abdalla and Libby ([58]) and Shabman and Bertelson ([37]). The average property value of a home on a block was treated as the dependent variable in a regression model in which a dummy variable was used to distinguish waterfront acreage from fastlands acreage. The waterfront amenity had a significant impact on the prices of homes; the estimated impact on realty values was about $150 per wetland acre. Thibodeau and Ostro correctly impute the increase in property value due to the waterfront amenity as a preservation benefit of the wetland; Abdalla and Libby incorrectly impute the location-generated realty price differential to the development process.

58. Abdalla, C.W., and L.W. Libby. 1982. Economics of Michigan wetlands. Agricultural Economics Report No. 410, Michigan State University, East Lansing. 32 pp.

This paper deals with a problem that is the inverse of the problem of assessing the nonmarket benefits provided by wetlands. Abdalla and Libby examine the location value of real estate that is located in the vicinity of various Michigan wetlands. As the authors point out, economic efficiency requires that the wetlands be allocated so as to maximize the total social value of the resource.

The wetlands in question have frontage strips that are all suitable for real estate development. The "value of development" refers to the fact that a developed (improved) lot is worth more than an undeveloped lot, and the greater the value of the improvement expenditures, the greater the price of the lot. Conceptually, the development value of the resource can be measured as the differential between the return to a given development expenditure on a lot near the wetland, and the return to the same expenditure on the next most advantageous site. The marginal contribution of the wetlands to the price of the lot (development versus undeveloped differential) can be rigorously determined through a multi-variate regression analysis in which the price of a developed lot is the independent variable and the distance between the lot and the wetland and the waterfront footage of the lot are used as independent variables along with the value of the improvement expenditures.

Still, the analysis seems confused in attributing the variation in lot price (as a function of distance from the wetland) as an attribute of the

development process. The correct procedure would be to consider the differential in lot prices due to location relative to the wetlands and wetlands waterfront footage as a wetland preservation benefit. This was the procedure used by Ostro and Thibodeau (see [58]) in their paper on the Charles River wetlands near Boston.

59. Bunbridge, P.R. 1982. Valuation of tidal wetlands, saltmarshes, tidal swamps, swamp forest. Pages 43-64 <u>in</u> C.H. Soysa, D.L. Sien, and W.L. Collier, eds. Man, land, and sea: coastal resource use and management in Asia and the Pacific. The Agricultural Development Council, Bangkok.

The article is really a critique of natural resource economics, and does not focus very closely on wetland resources. The author argues that the economic valuation approaches he discusses do not adequately address fundamental particularities of the wetlands preservations issue. These valuation approaches include the market externalities approach, the option value approach, the existence value approach, and the ecosystem life support or energy theory of value. Bunbridge cites various authors who believe that these concepts all are mere window dressing, and that the substantive part of formal economic analysis deals almost entirely with the allocation of privately owned goods and services through the price system.

The concept of an "externality" is fundamental to Bundbridge's discussion. An externality exists if Mr. A's purchase of and use of a good affects Mr. B's level of welfare. This situation could arise in a variety of ways. Mr. A might purchase a noisy power lawnmower that shatters the peace and quiet of Mr. B's Sunday mornings (externalities in consumption). Mr. A and Mr. B might both be businessmen located in the same shopping mall. Mr. A's sale might attract people to the mall who spend money at Mr. B's, in which case Mr. B's level of profit is affected by the volume of business done by Mr. A (nonpecuniary externality in production). Clearly, mild externalities in exchange economies are the rule rather than the exception. However, the study of the efficient allocation of resources in the complete absence of all externalities can be interpreted as a paradigm about a tendency of the market allocation of goods and resources to be tolerably efficient as long as every dollar competes with every other dollar in the budgets of individual consumers. This is a point of view that is heavily criticized by Pope and Gosselink ([9]). It can also be interpreted as a description of how difficult it will be to achieve reasonable economic efficiency and distributional equity for goods and services that exhibit truly sizeable externalities with or without the use of the market mechanism. Unfortunately, this point-of-view is not raised in this article, nor is it considered by Pope and Gosselink ([8]).

However, the article is balanced, if almost completely negative, in its assessment of the various modifications of conventional economic analysis that have been attempted in order to impute large preservation benefits to natural resources such as wetlands. The criticism of the work of Gosselink, Odum, and Pope ([9]) and Pope and Gosselink ([8]) on ecosystem life support functions performed by wetlands is just as even-handed as the criticism of the more conventional theories.

60. Linder, R.L., and D.E. Hubbard. 1982. Wetland values in the prairie pothole region of North America. Pages 27-39 in Proceedings of the Great Plains Agricultural Council, No. 5. [Held in North Platte in June, 1982]. Lincoln, Nebraska.

This is a remarkable piece of work in that it presents no formal economic data, but the authors communicate the political and rhetorical persuasive force of economic analysis. Thus there is no doubt that all of the wetlands functions discussed have positive marginal social value; Linder and Hubbard clearly understand the usefulness of demonstrating this point.

Hammack and Brown (see [10]) show that provision of breeding habitat for migratory waterfowl has a positive social marginal value product. Their work is one of many cited by Linder and Hubbard in their useful and extensive bibliography. Linder and Hubbard provide some quantitative biological data and much qualitative data that supports their contention that prairie pothole ponds are important migratory waterfowl habitat. Moreover, the quantity of this habitat type is a limiting factor in the production of ducks and other valuable waterfowl species. Linder and Hubbard also make a case for considering prairie potholes to be limiting habitat (have positive marginal social value product) in the production of such species as wren, blackbirds, white-tailed deer, pheasants, and muskrats.

Much of the social importance of the hydrologic functions considered by Linder and Hubbard lies in the fact that the underlying critical hydrologic relations seem to be roughly linear (as a function of the areal extent of the regional wetland acreage). Therefore, the social marginal value product of the functions is, roughly, a positive constant. These include flood amelioration and prevention, groundwater storage, and groundwater retention. An important social corollary of the groundwater retention function is that undrained wetlands can support vegetation during protracted droughts that wipe out other sources of livestock feed. The wetland vegetation from undrained on-farm wetlands can be used as forage for livestock during periods of drought because of the remarkable groundwater retention and storage functions provided by certain of these wetlands. Linder and Hubbard do a noteworthy job of reviewing and condensing the relevant literature. But more research is needed to impute dollar values to the various hydrologic functions.

61. Bowers, J.K. 1983. Cost-benefit analysis of wetland drainage. Environment and Planning (A) 15:227-235.

The author argues that proposed social investments in wetland conversion projects in England have been the subject of seriously defective cost-benefit analyses that overstate the benefits of private and social investment in wetlands conversion and drainage, and grossly understate the costs. The projects include public investment for flood protection on the Yare, Parrett, and Prue River basins. The projects would raise the profitability of private drainage investment in the three basins.

First, no amenity benefits to wetlands preservation are deducted from the gross stream of market receipts from the private use of the drained wetlands. These benefits are a social opportunity cost of development and must be deducted

from the private net development benefits in calculating the total social return to drainage investment. Second, the extra farm output that results from wetlands drainage is valued in prices that include tariff protection and government commodity price support components. These components are transfer payments, and should be netted out from the social return on investment calculations. Third, the yield increases are estimated for the most productive lands and do not represent average farmland productivity. There are other technical difficulties in these calculations; the author makes a convincing case that an irrational pro-conversion bias underlies the proposed development projects.

62. Craft, B.R. 1983. Louisiana story: the gulf coast wetlands. Pages 262-267 in The yearbook of agriculture. U.S. Department of Agriculture, Washington, DC.

This paper is similar to ([63]). Craft estimates that losses of Louisiana coastal wetlands total 40 square miles per year. These marshes provide overwintering habitat for migratory waterfowl and for important fur-bearing species such as muskrat, nutria, racoon, otter, and mink. The annual Louisiana fur harvest ($8.5 million in 1982) is greater in value than that of the rest of the U.S. and Canada combined. And from 1976 to 1981, a total of 58,725 alligators were harvested in these wetlands. Larval and juvenile forms of finfishes and crustaceans, including such economically significant species as shrimp, blue crab, croaker, menhaden, mullet, and bay anchovy, use the estuaries and marshes before migrating to open sea. In 1982, Louisiana produced 1.6 billion pounds of commercial fish, with a combined dockside value of $221 million. The State produces 50% (by value) of the U.S. commercial harvest of oysters and crabs.

Saltwater intrusion kills freshwater marsh plants, in turn destroying the surface vegetative mat and dispersing the organic soils of the freshwater marshes. This leads to conversion of freshwater marshes to open seawater. Various protective measures (weirs, levees, the use of plants for erosion control) could substantially slow the wetland loss. Some economic analysis is needed to estimate the magnitudes of the costs and returns for these preventive measures.

63. Davis, D.W. 1983. Economic and cultural consequences of land loss in Louisiana. Shore and Beach 51(40):30-39.

Louisiana's costal wetlands are being lost at the rate of about 25,000 acres per year. There are a variety of causes for the loss of this resource, including channel and canal dredging by man, seawater intrusion, subsidence, and shoreline erosion. The loss of coastal wetlands entails a loss of habitat for such economically significant species as migratory waterfowl and shrimp. In 1983, these wetlands still totaled 6.5 million acres.

64. Leitch, J.A. 1983. Economics of prairie wetland drainage. Transactions of the American Society of Agricultural Engineers 26(5):1465-1470.

This paper analyzes the same data on drainage costs and gross and net returns to drainage investment that was presented in earlier papers by Leitch ([48]), and Leitch and Kerestes ([49]). There were two study areas from which

data on drainage costs and gross and net rates of return were calculated, a region in west-central Minnesota and a region in south-central Minnesota. The publication of analyses of the same data in three different places is partly justified by the rarity with which data on drainage costs has been presented in the literature on wetlands. The data analyzed in the three studies was obtained from a survey instrument; the sample size (35 respondents) was, unfortunately, remarkably small. Leitch and Kerestes ([49]) reported that many farmers who were rumored to have recently drained wetlands refused to respond to the survey.

One important policy implication that is bought to the fore in this paper is that the rate of return on nearly half the drainage investment projects in the west-central Minnesota study area had a net present value that was less than the average present value yielded by participation in one of the U.S. Fish and Wildlife Service's preservation programs. Payment levels in the programs are geared to foregone earnings from drainage, so the calculations of foregone earnings have significant policy implications. However, the fact that the respondents chose to drain rather than enroll their wetland acreage in a preservation program suggests that nonpecuniary benefits may provide a more important incentive for drainage activity than the Service realizes.

Leitch cites a study that indicates that the U.S. Fish and Wildlife Service paid an average of $847 per hectare for easement leases in the west-central Minnesota study area in 1980. The west-central Minnesota study area was composed of two subareas, a northern and a southern area. One reason for this division was that the pattern of output differed sharply between the two regions. Average net returns to ditch drainage in the northern subarea was $529 per hectare before taxes, using a 15-year life of investment and 8% discount rate; in the southern subarea, they were $1,499 per hectare. Average, before tax, discounted return (8% discount rate) to tile drainage investment in the southern subarea was $583. In the northern subarea it was negative (-$388 at 8% discount rate). General (or supplemental) field drainage is popular among southern Minnesota and Iowa farmers. These projects (multi-farm) drain excess moisture and enhance productivity from croplands; they also drain water from wetlands. The respondents were asked to estimate the profitability of general field drainage for their wetlands, but it was clearly a somewhat artificial issue from the farmer's perspective. The discounted (8% discount rate) net before tax return to general field drainage in the south-central Minnesota study area for wetlands was $2,193 per hectare. For removal of excess soil moisture it was only $635 per hectare.

65. Turner, R.K., D. Dent, and R.D. Hay. 1983. Valuation of the environmental impact of wetland flood protection and drainage schemes. Environment and Planning 15(7):871-888.

One of the most widely appreciated alleged beneficial functions performed by riparian corridor and coastal wetlands is flood control. The Yare Barrier Proposal in Norfolk, England, is a large wetlands conversion and flood control project. Flood control enhancement would be provided by a tidal surge barrier (a drop gate) near the mouth of the River Yare, together with improvements to existing floodwalls on the Rivers Bure, Waveney, and Yare. The flood protection enhancement project would provide protection from freshwater and seawater flooding and North Sea tidal surges for the extensive low-lying regions of the

Yare River basin. The flood enhancement project would augment the returns to on-farm drainage investment by farmers of the low-lying wetlands in the Yare River basin. About 25,000 hectares of this region are below river level, and these lowlands include some of the more important migratory waterfowl habitat in Northern Europe. Also, these wetlands, though they no longer contain the original flora of the region, are very beautiful and contain an assemblage of flora that is highly prized throughout England.

The authors show that the private returns to on-farm drainage of the wetlands will range between 35% and 65% (if the Yare Barrier is built). However, the social returns to drainage are far lower than the private returns. The social cost to drainage must net out the cost of the crop price support for wheat (the most profitable agricultural crop for the potentially highly productive soils of the region) and the cost of maintenance and construction of the flood control structures. Also, certain other social costs must be incurred, including the construction of roads and the capital costs of the regional drainage systems. The farmers do not actually incur regional drainage system costs in these private return calculations; moreover, drainage investments undertaken by individual entrepreneurs are heavily subsidized.

The total impact of these effects is to lower the net social rate of return on these investment projects below 5%. The moral of the story is that social and private benefits of wetlands drainage projects can diverge markedly. However, if private benefits are high, development pressures will also be high.

66. Bardacki, M.J. 1984. What value wetlands? Journal of Soil and Water Conservation 34(3):166-169.

Bardecki argues that wetlands provide important wildlife habitat benefits. However, he believes that they may not provide significant flood protection or groundwater recharge benefits. Bardecki strongly defends the notion that wetlands significantly enhance water quality, though the use of wetlands for tertiary treatment of wastewater may be limited by the inability of the wetland plants to withstand the stresses imposed by the pollution load. Bardecki asserts that almost all creditable economic analyses of wetland preservation benefits and private returns show a great disparity between the social and private benefits provided by wetlands. More precisely, he states that numerous studies have shown that the private returns to wetland ownership are less than 20% of the total value of the social benefits provided by wetlands. This discrepancy between social and private returns gives rise to a marked tendency for the resource to be misallocated by purely market forces.

67. Leitch, J.A., K.W. Easter, and W.C. Nelson. 1984. A proposed framework for developing a multidisciplinary wetlands valuation model. The Environment Professional 6:117-124.

This is a complicated article. Leitch et al. develop complex flowcharts for analyzing relations between wetlands and various policy instruments. The authors propose that a research team composed of physical scientists and social scientists define and estimate production and ecologic relations for wetlands, and that this study team define the relevant socioeconomic uses of the various wetlands outputs and uses. Other proposed topics for the study team include the

analysis of the interface between the two types of processes and the study of the impact of internal and external perturbations on wetlands and the various systems that pertain to wetlands, their management, and their human uses.

The proposal of the authors to sequester beneficiaries of wetland values into owner, user, regional, and national groups could lead to double- and triple-counting of wetland outputs.

68. Leitch, J.A., and D.F. Scott. 1984. Improving wetland policy through amelioration of adverse effects on local economies. Water Resources Bulletin 20(5):687-693.

Leitch and Scott use an input-output model to estimate the changes in gross expenditure patterns and net income flows that would result from the restoration of prairie potholes. Some subsidization payments over and above the lost income of the landowner would probably be required to make these local economies as robust after restoration as they were before restoration.

69. Nelson, R.W., and W.J. Logan. 1984. Policy on wetland impact mitigation. Environment International 10(1):9-19.

This is a policy-oriented article that examines the implementation of the 404 permit application process. Nelson and Logan discuss national and site-specific mitigation impact policies for the granting of 404 fill and dredge permits by the U.S. Army Corps of Engineers. The general permits that are currently being issued by the Corps allow the discharge of dredged or fill material; they do not require any site-specific permit application or even notification by the permittee. These general permits allow the bedding of pipelines or the placement of minor roadway fills in any wetland on the presumption that these activities will not produce more than a negligible impact. However, this presumption is invalid according to the U.S. Environmental Protection Agency, which would like to prohibit any dredge or fill discharges in which unacceptable adverse effects on municipal water supplies, recreation benefits and activities, or fish and wildlife habitats would result. The U.S. Fish and Wildlife Service also deems this presumption invalid. The Service would like to assign a very high value to certain aquatic and wetland fish and wildlife habitats; the preservation benefits of these habitats is so high, that no loss of habitat is acceptable.

The basic criterion suggested by Nelson and Logan for choosing between site-specific mitigation proposal permits and national permits and mitigation policies is economic. National mitigation requirements are less costly to administer, and the authors find this approach valid for low value wetlands when the dredge and fill activities are likely to cause minor, short-term damage. When damage is irreversible or long-term, or the wetlands has high value, site-specific mitigation proposals should be used; the potential benefits from the use of this permit policy outweigh the greater cost according to Nelson and Logan.

70. Smutko, L.S., J.A. Leitch, L.E. Danielson, and R.K. Stroh. 1984. Landowner attitudes toward preservation policies in the prairie pothole region. Agricultural economics miscellaneous report no. 78, North Dakota State University, Fargo.

Nonpecuniary returns to on-farm wetland drainage investment by farmers may be an important factor underlying agricultural wetland conversion and loss, but these returns are difficult to quantify. Smutko et al. attempted to assess a factor associated with nonpecuniary returns, namely the attitude of landowners with respect to the U.S. Fish and Wildlife wetland preservations programs and the Agricultural Soil Conservation Service waterbank program. The survey indicates that the success of the Federal and State wetland preservation efforts could be improved by keeping the public better informed about the program and its goals and by increasing the monetary incentives for potential participants. One interesting qualitative variable that is positively correlated with positive attitudes toward the preservation programs is fondness for hunting. The authors found that the prices of fee simple purchases in certain areas were $200 less than the market value of the land (of course for a pothole to be productive, it must be drained at positive cost). However, in those geographical areas in which the attitudes of the farmers were favorably disposed to participation in the easement program, farmers were willing to sell land to the U.S. Fish and Wildlife Service at less than market prices. Hence the authors suggest that the preservation effort be targeted toward such regions.

71. Barbard, W.D., C.K. Ansell, J.G. Harn, and K. Daniel. 1985. Establishing priorities for wetland management. Water Resources Bulletin 21(6):1049-1054.

The authors argue that implementation of section 404 of the Federal Water Pollution Control Act of 1977, in conjunction with State programs, is responsible for reducing wetland conversions to 50% of the permit application rate. An important assumption underlying the paper and research approach is that the permit applications are a significant fraction of the actual dredge and fill activity that occurs in wetlands.

72. Batie, S.S., and C.C. Mabbs-Zeno. 1985. Opportunity costs of preserving coastal wetlands: a case study of a recreational housing development. Land Economics 61(1):1-9.

This paper also studies the economics of wetlands development. Batie and Mabbs-Zeno use a hedonic price model to quantify and estimate the price of lots at the Captain's Cove subdivision on Virginia's eastern shore. The approach is similar to that used by Abdalla and Libby ([58]), Shabman and Bertelson ([37]), and Ostro and Thibodeau ([57]). The regression model relates lot characteristics to lot prices for suitable sample lots; independent variables for this regression include four dummy (binary) variables that indicate the presence or absence of amenities such as waterfront footage, canal front footage, placement next to a wetlands, and sewer access. The regression results were used to provide a statistical estimate of gross returns to investment in lot improvements (while holding various economically significant physical characteristics of the lot constant). Cost construction data were not available, but cost estimates were

provided by local construction firms. Net returns to development were also a function of the presence or absence of suitable nonwetlands alternative sites.

73. Adamowicz, W.L., W.E. Phillips, and W.S. Pattison. 1986. The distribution of economic benefits from Alberta duck production. The Wildlife Society Bulletin 14:396-398.

This paper presents some interesting and useful data on duck production and the geo-political distribution of the hunting benefits generated by ducks breeding on Alberta (Canada) prairie potholes. The prairie potholes constitute only 10% of the total waterfowl breeding habitat (area) of North America, but produce 50% of the waterfowl. The authors estimate benefits for the following groups: (1) Alberta waterfowl hunters who live and hunt within Alberta, (2) Canadian waterfowl hunters who hunted in Alberta but do not reside there, (3) U.S. residents who hunted in Alberta, and (4) U.S. residents who hunted, but not in Alberta. These calculations show that 85% of the benefits of hunting ducks that use Alberta prairie potholes are enjoyed by U.S. residents. The benefits are estimated by willingness-to-pay above costs and license purchases. For 1984, U.S. residents hunting in the U.S. enjoyed annual net benefits of $10,395,680 from hunting waterfowl produced in Alberta.

74. Danielson, L.E., and J.A. Leitch. 1986. Private vs. public economics of prairie wetland allocation. Journal of Environmental Economics and Management 13(1):81-92.

The data presented here on costs and returns to on-farm wetland drainage seems to be a subset of the data on private net returns to drainage activity given in earlier work by Leitch (see [48] and [64]), and Leitch and Kerestes ([50]). The data on costs, which was generated by the use of a survey instrument, is for a region in west-central Minnesota. Random wetland drainage is common in this region. Leitch reports a large variation in per acre drainage costs in this region; this is probably the result of differences in topography rather than the small sample size (only 35 usable surveys on drainage costs and returns were obtained). The reported activity spanned the 1970-1980 period; all figures were adjusted for inflation and reported in 1980 dollars. Eight respondents who reported ditch drainage costs and returns in 1980 produced an average per acre cost of $145 per acre; for tile drainage, 6 respondents indicated that the average per acre cost was $626 per acre. Estimates of net returns to tile drainage activity were not listed, though Leitch indicates that they were positive, but significantly lower than for ditch drainage investment. Present values for net after tax returns for ditch drainage averaged about $154, using a 8% discount rate.

The first part of the paper is an intelligible, self-contained graphical analysis of the divergence between social and private returns to drainage investment. Unfortunately, the highly condensed journal format makes it a bit difficult to follow the argument. In particular, the explanation as to why the minimal payment that will induce the farmer to accept the socially optimal level of drainage is compensation for pecuniary foregone income comes much too late in the discussion. The reason is that total returns to drainage investment are the sum of pecuniary returns and nonpecuniary returns. Compensation for lost

pecuniary income will not be sufficient to induce the farmer to give up conversion if nonpecuniary returns are large and positive.

Another interesting omission in the article is adequate discussion of the anomalous empirical finding that there are significant nonpecuniary returns to participation in the U.S. Fish and Wildlife easement and fee title wetland preservation programs. Danielson and Leitch report the results of a survey of Minnesota farmers that elicited their responses toward participation in various wetland preservation programs. The average price at which they would sell land to the Service in a fee title purchase was only $583 per acre in a region in which the average market price of cropland was $736. Discussion of this point would resolve a discrepancy between the theory and the data presented in this paper.

75. Heimlich, R.E. 1986. Economics of wetland conversion: farm programs and income tax. National Wetlands Newsletter 8(4):7-10.

The swampbuster provisions of the Food Security Act of 1985 attempt to slow wetland conversion and drainage by farmers by denying Federal farm program benefits to any farmers who drain and convert wetlands. Benefits are denied on all cropland owned by the farmer, but the sanction is applicable only for years when annual crops (or certain agricultural commodities such as hay) are actually planted on the former wetland acres. The programs involved include commodity price support and disaster payments, crop disaster insurance, and subsidized loans. Heimlich considers the potential impact of the swampbuster legislation and makes a brief assessment of the potential impact of pending Federal legislation that would restrict tax code provisions that reduce the after tax cost of wetland conversion by farmers.

The author believes that the impact of swampbuster on wetlands loss will be negligible despite the fact that the U.S. Fish and Wildlife Service estimates that 85% of the wetlands loss in the postwar era is due to agricultural conversion. There were 78.4 million remaining non-Federal wetlands in 1982; half had no estimated yields for crops covered by swampbuster. Less than half of the remaining 38.9 million acres would yield positive profits if converted to cropland, and 15.9 million acres of wetlands would yield a positive short run profit net of conversion costs if they were allowed to participate in Federal programs. However, 13.9 million of these acres would not yield a positive short run return to drainage investment if they were not allowed to participate in the price support program.

The sluggish farm economy of the mid-1980's retarded all farm investment activity, including wetland drainage, by farmers. It was more profitable to purchase or lease existing farmland than to drain wetlands for agricultural use. Heimlich asserts that the income foregone from loss of Federal benefits is much greater for the average farmer than the income gained from drainage. But this is more than counterbalanced by the fact that crops that are likely to be grown on converted wetlands (such as soybeans) are not heavily supported. Moreover, the regions that have high conversion potential wetlands and areas where remaining wetland conversion to farmland might be profitable have low Federal farm program participation rates.

The cost of clearing the land (under most circumstances) was tax deductible, as were many of the drainage costs, when Heimlich wrote this paper. Heimlich provides an instructive hypothetical example in which almost one-third of the per acre $900 loss in farm income from application of the swampbuster sanctions to a farm in the North Carolina pocosins is offset by the tax shelter provisions favoring farm drainage investment. Tax code changes that remove provisions favoring drainage investment were instituted shortly after Heimlich wrote this article.

76. Heimlich, R.E., and L.L. Langner. 1986. Swampbusting: wetland conversion and farm programs. U.S. Department of Agriculture, Economic Research Service Agricultural Report No. 551, 7 pp. Washington, DC.

Conversion and drainage of wetlands to farmland is called "swampbusting." Under the swampbuster provisions of the Food Security Act of 1985, farmers who grow agricultural crops on converted wetlands will be denied all Federal farm program benefits. Agricultural conversion was responsible for the loss of 12 million wetland acres during the 20-year period between the mid-1950's and mid-1970's. The authors use farm simulation calculations to show that the swampbuster legislation will slow the rate of conversion. The problem is that the deceleration induced by swampbuster in the conversion rate may not be socially significant. If the conversion costs are high (as they would be for the pocosins of North Carolina), the sanctions will have less bite than for low-cost conversions. Low conversion costs are still typical of prairie pothole conversions.

77. Maltby, E. 1986. Waterlogged wealth: why waste the world's wetplaces. International Institute for Environment and Development, London, England. 198 pp.

Many of Europe's wetlands have been lost to conversion and drainage by humans. Maltby asserts that European wetlands provide flood control, groundwater recharge, pollution reduction, and recreation sites. He examines the role of subsidization of private wetland conversion activity by various European governments.

78. Nelson, R.W. 1986. Wetlands policy crisis: United States and United Kingdom. Agriculture, Ecosystems and Environment 18:95-121.

This article offers little economic analysis, and the economic data on U.K. and U.S. wetlands is scattered and piecemeal. The main thrust of the article is to show that recent legislation regulating conversion and drainage of wetlands is watered-down by a broad gamut of governmental and bureaucratic attitudes and practices that usually lie outside the regulatory framework of the legislation. Moreover, while the U.S. Federal Government has dismantled many of the programs of the past that subsidized agricultural drainage of wetlands and replaced them with legislation and regulations that provide stiff disincentives to farmers who might drain their wetlands, the U.K. still has little legislation that discourages wetland drainage.

The most interesting economic data cited by Nelson show that the rate of return on drainage investment by U.K. farmers is still remarkably high (35%-65%

internal rate of return on field drainage investment in lowland meadows with good clay soils). From a policy perspective, perhaps the two most important reasons for this high rate of return are the ongoing government investments in public drainage and water projects that often greatly increase the physical effectiveness of each private dollar spent on drainage activity. Also, there are still certain U.K. government programs that directly and indirectly subsidize agricultural drainage of wetlands, including U.K. tariffs and quotas on agricultural products. Some of these indirect subsidies also affect drainage investment in the U.S., though the impact is difficult to measure.

79. Farber, S., and R. Costanza. 1987. The economic value of wetlands systems. Journal of Environmental Management 24:41-51.

Costanza and Farber apply both the conventional methodology of marginal economic analysis and an energy theory of value approach (see [8] and [9] for discussion of the energy theory of value or ecosystem life support function approach to wetland valuation) to assess the amenity values provided by a wetland system in Terrebone Parish, Louisiana. They attempt to make a summary estimate using the conventional approach by employing the reasonable assumption that the outputs they consider have a total value that can be derived by adding the values of the individual goods and services. Costanza and Farber estimate a marginal value product for wetlands in commercial harvesting, an aggregate willingness-to-pay or consumer surplus figure for the social benefits conferred by recreational activities pursued on these wetlands, and a wind damage protection amenity value conferred by the wetland.

Costanza and Farber estimate a marginal value product for wetlands in the commercial harvesting of shrimp, blue crab, oyster, menhaden, and commercial trapping (primarily for nutria and muskrat). To estimate the marginal product of wetland acreage in shrimp production, the authors first tried to estimate an equation introduced by Lynne, Conroy, and Prochaska (see [51]) to calculate the marginal product of wetlands in the harvesting of blue crabs:

$$Q = B_o + (B_1 E) \ln W_{-1} + (B_2 E^2) \ln W_{-1} + B_3 Q_{-1} + \sigma.$$

In the above equation, Q is the annual harvest, E is a scaler measure of human effort (quantified as the number of man-hours for the shrimp harvesting equation), W is a scaler variable that quantifies the habitat (environmental) input, and σ is a random error term. The subscripts indicate lagged variables; thus habitat of the previous year determines the size of the current harvest. However, when this equation was regressed on annual data by Farber and Costanza, the estimated coefficient for the quadratic term in E had the wrong sign. Note that the marginal value product of habitat (partial derivative of Q with respect to W) is

$$MP = (B_1 E + B_2 E^2) W^{-1} .$$

Farber and Costanza estimated a static version of the harvest equation used by Lynn, Conroy, and Prochaska ([51]) in which only the current value of the habitat variable is used to explain the harvest level. The estimated annual marginal products were 1.60 pounds per acre for brown shrimp, 1.44 pounds per acre for white inshore shrimp, and 0.90 and 1.23 pounds per acre for white and

brown offshore shrimp, respectively. A similar technique was used to estimate a marginal value product for tidal marsh acreage in the harvesting of oysters. They used the figure provided by Lynne, Conroy, and Prochaska ([51]) for the marginal value product of marshland acreage in the harvesting of blue crabs. For menhaden harvesting and for trapping, they imputed the entire market value of the harvest to the marsh. However, the estimated marginal value product of the various harvests was only $37.46 per annum per acre in 1983 dollars.

To estimate the consumer surplus for the various recreational activities (hunting, fishing, boating, and shoreline activities) pursued at the wetlands, both the travel cost (TCM) and contingent value (CVM) methodologies were employed. The TCM produced an estimated consumer surplus of $6.00 per annum per acre, while the CVM produced an estimated consumer surplus of $4.86 per annum per acre. In previous research, Farber had estimated a wind damage decay function, in which hurricane wind damage was allowed to diminish as the distance from landfall increased. The wind damage decay is a function of the distance traveled by the storm over wetlands. This functional relation was the basis for the estimated social marginal product of wetlands in providing storm damage protection. The estimated value, $0.48 per annum per acre, was small, but not insignificant. Moreover, these estimates suggest that flood protection provision may be a very important social benefit conferred by tidal wetlands systems; wind damage is only 5.4% of total storm damage in the wetland region. The total annual benefits flow for the provision of habitat, recreation, and storm protection is $43.90 per acre. The present value of the discounted infinite horizon benefits stream, using an 8% discount rate and the conventional methodologies is $568.73. A 2.6% rate of population growth is incorporated in the capitalized values of the recreation benefits.

The imputed per acre value of tidal marshland derived from the energy analysis evaluation, which is highly similar conceptually with the imputed value for the ecosystem life support function of Pope and Gosselink (see [8]), is much larger. It lies somewhere in the $6,400-$10,602 range (discounted per acre value at 8%). Costanza and Farber estimate the plant biomass production per annum per acre of marsh, and convert this number into a fossil fuel energy consumption equivalent. The fossil fuel equivalent was then used to determine a dollar value for the production of primary plant biomass. Some of the conversion factors and other pertinent details are omitted from the summary discussion.

80. Goldstein, J.H., and B. Wilen. 1987. Response to an assessment of the impact of Federal programs on prairie pothole drainage. National Wetlands Newsletter 9(6):11-12.

The authors were the project officers for a research project initiated by the U.S. Fish and Wildlife Service to estimate the potential effectiveness of the swampbuster provisions of the Food Security Act of 1985 in slowing farmland conversion and drainage of wetlands. The results of this research project were discussed in the National Wetlands Newsletter (see [81]). Goldstein and Wilen have doubts about the validity of the conclusions reached by McColloch, Wissman, and Richardson ([81]) in that study with regard to the efficacy of swampbuster in slowing wetland drainage in the prairie pothole region of the northern Great Plains of the U.S. McColloch, Wissman, and Richardson ([81]) used a farm simulation computer model to show the impact of the swampbuster legislation on

the net present value of a group of hypothetical farms. Investing in farmland drainage raised the net present value of the model farms, even though they were unable to participate in various Federal farm programs because of swampbuster.

Goldstein and Wilen raise some interesting objections with regard to extrapolating the results of the computer simulation runs to the entire agricultural sector of the U.S. economy. They point out that the swampbuster legislation penalizes a farmer who drains an on-farm wetland by making it impossible for him to participate in various Federal farm programs during any year in which he plants crops on the drained land. The sanction is severe in that it applies to all farms owned by a farm operator. Failure to include multiple farms operated under single person or family ownership imparts a downward bias in the quantitative estimates of the overall impact of swampbuster reported by McColloch, Richardson, and Wissman. According to Goldstein and Wilen, multiple farm ownership is fairly common.

Swampbuster should be most effective in regions of the U.S. that have a high ratio of uplands acreage in crop production relative to the acreage of existing on-farm wetlands. It should also be most effective in the regions of the country that have a high participation rate in Federal farm programs. Both considerations--high participation rate and favorable uplands to wetlands ratio--are applicable to the prairie pothole region. Goldstein and Wilen also point out that net present value is only one index of the net returns to farming because farming is a risky activity. The reduction in risk from participation in the Federal farm programs is an important benefit that is not captured in the net present value calculations.

All of the drainage activity in the model occurs in the first year of the 10-year simulation run. Capital markets are not perfect, however, and the on-farm wetlands would more likely be drained over a long period of time. Swampbuster legislation would be more effective in preventing a series of staggered wetlands drainage investments by a farmer than it would be in preventing drainage by a farmer whose net worth positions enabled him to drain all of his wetlands in one year. But this last consideration, the timing of drainage investment activity, raises an issue that was neglected by McColloch et al. ([81]), as well as by Goldstein and Wilen. The swampbuster legislation allows the farmer to participate in Federal farm programs when agricultural product prices are low, and plant crops on his former wetland acreage when prices are high, because sanctions apply only during a year in which the farmer plants annual crops on the drained wetland acreage.

81. McColloch, P., D.J. Wissman, and J. Richardson. 1987. An assessment of the impact of Federal programs on prairie pothole drainage. National Wetlands Newsletter 9(4):3-6.

McColloch et al. examine the effectiveness of the swampbuster provisions of the Food Security Act of 1985 for farms in the prairie pothole region of the Great Plains. The prairie pothole region of the U.S. covers about 60,000 square miles; in conjunction with the prairie pothole region of Canada it provides the bulk of the migratory waterfowl habitat of North America. Prairie pothole wetlands and adjacent uplands (which are sometimes said to form a wetlands-uplands complex) are also alleged to provide important habitat for such

commercially significant species as mink, beaver, raccoon, red fox, muskrat, rabbit, deer, sharptail grouse, and ringneck pheasant. They may also provide major nonmarket hydrologic benefits through groundwater recharge and storage functions, as well as flood amelioration benefits. However, only 25% of the Nation's original wetland endowment remains.

The authors use a farm simulation computer model to examine the relative magnitudes of the change in the after tax net present value from pursuing two types of management policies for farms of various (hypothetical) sizes and types. The model is called the Farm Level Income and Policy Simulation Model (FLIPSIM). The simulation procedure incorporates the influence of a number of random factors (such as the weather) as well as the impact of the policy variables in question on the net present value of the farms. The simulation runs covered a 10-year planning horizon; the financial position at the end of one year is the financial position for the start of the next year. The two policy alternatives involve draining or not draining an on-farm prairie pothole. However, the most striking effects of the swampbuster provisions are not directed by the policy menus, because the farmer who drains cannot participate in any Federal farm programs. The FLIPSIM model used by McColloch et al. examines a one-program-deleted-at-a-time scenario in which the farmer is not a participant in each of five Federal farm programs considered, but is a participant in the other four programs considered.

The five programs include Federal farm income tax provisions, disaster insurance and assistance programs, subsidized loan programs, wetland acreage conservation programs (the U.S. Fish and Wildlife Service Easement Program, as well as the Agricultural Stabilization and Conservation Service Water Bank Program), and the price support program. In every case, drainage yields a greater after tax net present value than wetland preservation combined with participation in all five of the Federal farm programs. Recall, however, that the likely impact of swampbuster is the loss of participation in all five of the extant programs, and this alternative was not examined in the simulation runs. One of the programs (the special wetland drainage tax provisions) was already defunct by the time that this paper was published. Apparently, the model was run before the passage of the Reagan tax reform bill in 1986 (or at least before tax code provisions favoring drainage investment were altered).

82. Bardecki, M.J. 1988. Impacts of agricultural land drainage on wetlands: a geographical appraisal. Pages 15-21 in P.J. Stuber, coordinator. Proceedings of the national symposium on protection of wetlands from agricultural impacts. U.S. Fish and Wildlife Service Biological Report 88(16). Washington, DC. 221 pp.

Two Provincial acts regulate the construction and maintenance of drainage works in the Canadian Province of Ontario. These are the Tile Drainage Act and the Drainage Act. Each provides for partial subsidization of private drainage investment. The Tile Drainage Act provides farmers who wish to drain their wet soils and wetlands with low cost loans. The loans are financed through the sale of debentures by the Province; the demand for the debentures varies with the robustness of the farm sector of the Provincial economy. The Province directly subsidizes one-third of the total cost of drainage investment under the provisions of Ontario's Drainage Act.

The Canadian Federal Government has also directly subsidized drainage investment in Ontario. Drainage activity in Ontario peaked in the 1968-72 period, when a Federal initiative provided an additional one-third subsidy. More recently, the Federal Government has subsidized drainage investment in eastern Ontario through the Eastern Ontario Subsidiary Agreement. Subsidization of drainage investment by the Federal Government has been the major determinant of the level of drainage activity in the Province. Historically, 500-700 drains have been constructed annually; but this rose to a peak of 1,200 drains per year during the period when the Federal Government was effectively doubling the Provincial subsidization rate of 33% (to 66%).

Bardecki constructs an index that he calls the propensity to drain. The index formula is

$$PD = A^{-2} (W * C)$$

Where PD is the propensity to drain index; W is the area of soils whose crop production capacity is limited by excess soil moisture; C is the area of high (crop) productivity soil; and A is total area.

Mapping the PD index reveals that the greatest propensity to drain occurs in the area of longest and greatest drainage activity, which is the extreme southwestern part of the study area. The index mapping shows that the greatest future wetland losses may occur in those areas that combine a higher than average PD with large remaining wetland areas. Further analysis of the impact of agricultural drainage on wetlands in the study area shows that wetlands are typically drained after extensive initial drainage investment occurs. Moreover, some wetlands are drained as an indirect consequence of the installation of equipment whose primary purpose is to drain nonwetland areas.

Bardecki concludes that wetlands preservation efforts in Ontario would be aided by termination of Provincial subsidization of private drainage investment by farmers. But despite the fact that wetland drainage is often an indirect effect of drainage projects, he is not sanguine about the effect of preserving wetlands through a project-by-project review system. Drainage will eventually become a basinwide phenomenon, thereby rendering the review process ineffectual unless (and until) the underlying economic forces generating on-farm drainage investment dissipate.

83. Dinan, K.F. 1988. Wetland protection in the rainwater basin of Nebraska. Pages 65-67 in P.J. Stuber, coordinator. Proceedings of the national symposium on protection of wetlands from agricultural impacts. U.S. Fish and Wildlife Service Biological Report 88(16). Washington, DC.

This paper faces a problem and issue that is ducked in much of the economics and institutional literature on wetlands. A pervasive assumption in this body of work is that imputing large preservation benefits to wetlands will have the effect of slowing wetlands drainage and conversion. In the regulatory arena, it is usually assumed that if the 404 permitting process were applicable to on-farm wetlands, the regulatory process would provide a direct major impediment to agricultural drainage of wetlands. Dinan asserts that drainage of Nebraska's Rainwater Basin wetlands often involves 404 permit application.

The program is fraught with so much ambiguity and conflict that it not successful from either a conservationist or regulatory perspective. Major problem areas associated with the Clean Water Act Section 404 permit program include a history of intense interagency, public, and private conflict over the basic questions of what is a wetland; whether-or-not mitigation is reasonable for (the frequently occurring) after-the-fact permits; and the contingent loss of social benefits that seems to always follow permit issuance. To further protect the remaining Rainwater Basin wetlands and reduce protracted and bitter interagency squabbling from the application of the 404 permit process, the Advanced Identification of Disposal Sites Process (commonly called the 230.80 process) was instituted in 1985 in accordance with Section 230.80 of the 404(b)(1) guidelines of the Clean Water Act.

One objective of the 230.80 process was designation of wetlands in the 17 county Rainwater Basin area that were subject to 404 permit regulation and were unsuitable (from a conservationist perspective) for fill under Section 230.80 of EPA's guidelines for Section 404(b)(1) of the Clean Water Act. Another goal was to collect information for making jurisdictional and delineation determinations. Other goals and objectives of the interagency team formed to implement the 230.80 program included increasing public awareness of the 404 permit process and of the social benefits conferred by wetlands. The interagency team pursued various concurrent activities, such as construction an inventory of existing Rainwater Basin Wetlands and an economic study of wetland conversion.

The outside economic consultant hired by the Environmental Protection Agency concluded that drainage of on-farm temporarily flooded wetlands is marginally profitable; drainage of seasonally flooded and semi-permanently flooded wetlands for conversion to croplands is currently unprofitable. The unpublished research report is now being circulated to farmers throughout the 17-county region in an effort to persuade farmers to forego further drainage activity.

84. Dornfeld, R., J. Piehl, and T. Rondeau. 1988. Wetland potential on CRP Land. Pages 68-71 in P.J. Stuber, coordinator. Proceedings of the national symposium on protection of wetlands from agricultural impacts. U.S. Fish and Wildlife Service Biological Report 88(16). Washington, DC.

Private leasing of farm land for use as a hunting or fishing recreation site is fairly widespread throughout many regions of the country. Dornfeld et al. report on a program to lease certain on-farm lands for a wetlands (habitat) restoration project in the prairie pothole region (Douglas, Grant, and Ottertail Counties) of Minnesota. The farm lands in question were all enrolled in the U.S. Soil Conservation Service's Soil Conservation Reserve Program (CRP). The Conservation Acreage Reserve subtitle of the 1985 Food Security Act provided effective incentives to these Minnesota Farmers for enrollment in the program. In fact, the benefits of soil erosion reduction, crop surplus reduction, a guaranteed income for 10 years on the enrolled acreage, and wildlife habitat improvements were so attractive to area farmers that the large CRP enrollments overwhelmed regional USDA offices.

Land enrolled in CRP was the focus of an effort to find funding sources for wetland restoration efforts. The former wetlands in question had been

drained and converted to cropland by farmers who also wished to participate in the CRP program. The U.S. Fish and Wildlife Service made contacts, supervised habitat restoration activity, and arranged for payment for all bills. Financial donors for the reconstruction activity and the leasing arrangements include the U.S. Fish and Wildlife Service, Ducks Unlimited, Inc., and Coots Unlimited. Minimal emphasis was placed on mandatory and legalistic aspects of the leasing arrangements. The wetlands were not subjected to the swampbuster provisions of the Food Security Act of 1985. The authors conclude that an incentive-driven wetland habitat restoration program can be highly successful, but stress the critical importance of the CRP in providing an initial compensation measure for the withdrawal of land from crop production.

85. Douglas, A.J., and R.W. Keim. 1988. Private drainage investment and national wetlands loss. Pages 73-80 in P.J. Stuber, coordinator. Proceedings of the national symposium on protection of wetlands from agricultural impacts. U.S. Fish and Wildlife Service Biological Report 88(16). Washington, DC.

The authors present some empirical data and regression tests that pertain to the potential efficacy of the swampbuster provisions of the Food Security Act of 1985. The key difficulty in testing the basic premise that drainage investment is directly related to net after-tax farm income is that no time series or cross-sectional national data on investment costs is currently available due to the extreme within region variations in costs. Even if drainage investment is driven by a desire to maximize the net present values of the farmers, the verification of a stable relation between farm income and quantitative determinants of the profitability of such investment does not really indicate the magnitude of the impact of swampbuster. Cross-section (State) regression tests failed to reveal any stable, significant statistical relation between drainage area and wetlands loss; between drainage area and the areal extent of existing wetlands; between drainage area and per acre farm income; or between drainage area and per capita farm income. Similar time series tests failed to detect any statistical relation between farm income and drainage investment.

If nonpecuniary returns are the dominant force underlying drainage investment, the swampbuster legislation will clearly increase the cost of drainage investment. Hence it might have an appreciable impact on the rate of wetland loss. However, the impact will not be as great as it would be if the primary motive for drainage activity is maximization of the value of the future net income from farming. Of course without appropriate cost data, the regressions only suggest that nonpecuniary returns may be an important factor generating drainage investment.

The authors assemble National and State data that indicate that Federal payments to farmers are much greater than the potential net income provided by drainage. Hence their conclusion is, roughly, the opposite of McColloch et al.; namely, the swampbuster has plenty of leverage for slowing agricultural drainage of wetlands when participation levels in Federal farm programs is adequate.

86. Goldstein, J.H., project officer. 1988. The impact of Federal programs on wetlands, volume I: the lower Mississippi alluvial plain and the prairie pothole region. 114 pp. Department of the Interior, Washington, DC.

This publication encompasses a major research effort as well as an important policy review section. Some of the research on the prairie pothole region in volume one is by McColloch and Wissman; it is the same research reported earlier in a brief note by McColloch, Wissman, and Richardson (see [81]). The conclusions that McColloch and Wissman reach in the farm simulation model discussed in this lengthy monograph are essentially reversed in the discussion of the policy implications of the research. A review of the McColloch, Wissman, Richardson article ([81]) by Goldstein and Wilen (see [80]) sketches the analytic logic and date interpretation underlying Goldstein's policy position.

This monograph includes a policy review and recommendation section; an econometric analysis of the clearing, conversion, and drainage of forested bottomland hardwoods; and a farm simulation study of the same (clearance, conversion, and drainage of forested bottomland hardwoods) topic. The major study and policy conclusions reached by Goldstein and his staff are manifold. Briefly, the principal conclusions reached in the study for the forested bottomland hardwoods encompass the following points: (1) Federal flood control and drainage projects built in the delta during 1935-1984 accounted for about 25% of total wetland loss, the single most significant factor underlying wetland loss during the period; (2) the mainline levee system, which was largely built before 1935, is the second-most important factor underlying wetland loss; (3) the clearing of forested wetlands has been highly profitable in the past, but economic conditions no longer favor this type of investment; (4) Federal income subsidies, price crop supports, and special tax code provisions significantly increased the profitability and reduced the risk of conversion and agricultural development in the Delta; and (5) the swampbuster provisions of the Food Security Act of 1985 and changes in the tax code provisions that formerly favored wetland drainage will have a major impact on the rate of wetland conversion in the delta.

For the prairies, the following points summarize the principal study conclusions: (1) general economic conditions as they impinge on the net pecuniary and nonpecuniary returns to wetland drainage investment are the most important factor affecting the rate of drainage and conversion of wetlands in the prairie pothole region; (2) Federal farm programs, including price and income supports, have had a major impact on drainage rates; (3) tax incentives for wetland drainage have not had a major impact in this region; (4) drainage of prairie potholes has been aided by outlet ditches provided through construction of Federally aided highways; (5) major wetlands losses have been induced, in part or wholly, by Federal water management programs, including the construction of five large dams and reservoirs on the mainstem of the Missouri; (6) Pl-566 stream channelization also induced considerable wetland drainage; and (7) the swampbuster provisions of the 1985 Food Security Act will be effective in reducing the rate of wetland losses of on-farm wetlands if they are vigorously enforced.

The various policy recommendations build on recently enacted Federal legislation, such as the swampbuster provisions of the 1985 Food Security Act

and the Tax Reform Act of 1986. There is a suggestion that the Federal Water Resources Development Act of 1986 be extended so that only those activities involving clear national goals receive Federal financing, and that non-Federal benefits are paid for by non-Federal sponsors. Benefits of water projects should be estimated in prices that are free of the impacts of Federal and State farm programs. The provisions of the Tax Reform Act of 1986 should be extended to include gains from the sale of all converted wetlands. Federal aid for highway construction should carry penalties for the use of highway ditches for wetland drain outlets. The U.S. Fish and Wildlife Service should be a consultant on all Federally aided highway projects. The Service would alert the State agencies to environmentally sensitive resources affected by highway projects.

The mitigation requirements of the Water Resources Development Act of 1986 should be extended to all Federal projects affecting wetlands. The acquisition of wetlands through various Federal programs should be accelerated. Specific steps to facilitate this process include cost-sharing between State, Federal, local, and private agencies in wetlands restoration projects. Advantageous use of temporarily depressed farm land prices and earnings could augment wetlands acquisitions and easement purchases.

87. Heimlich, R.E. 1988. The swampbuster provision: implementation and impact. 1988. Pages 87-94 in P.J. Stuber, coordinator. Proceedings of the national symposium on protection of wetlands from agricultural impacts. U.S. Fish and Wildlife Service Biological Report 88(16). Washington, DC.

Heimlich points out that the traditional methodology for testing the effectiveness of the swampbuster legislation of the Food Security Act of 1985 is to build a causal model of wetland on-farm drainage that functionally relates the level of drainage to a group of quantifiable independent variables. The swampbuster sanctions of the Food Security Act of 1985 would operate by changing the magnitudes of some subset of the independent variables in a simple deterministic fashion. The great advantage of such a model is the clarity and simplicity it affords in describing the chain of causality linking policy shifts to changes in drainage activity. A paucity of data renders it virtually impossible to test a causal model of drainage activity by farmers. However, an abundance of data exists on wetlands and their distribution. Also, there are lots of data on farm income and other socio-economic variables that might determine the level of on-farm drainage of wetlands. Finally, there are some variables that indicate the potential leverage of Federal farm programs to impede wetlands drainage. Heimlich used a statistical technique called (principal components) factor analysis to examine cross-section (by county) data to see if various data from the three groups listed above could be effectively related to each other. The casual mechanism that would be "tested" by the use of ordinary least squares regression technique is "revealed" or delineated by the principal components factor analysis approach.

Heimlich's factor analysis model indicates that five factors can be cited as having a significant effect on the success of swampbuster. He lists these five factors as wetlands, importance of agriculture, cropland conversion potential, cropland change, and government farm payments. These five factors can be combined in various ways to indicate the likelihood of the success of the swampbuster program in deterring wetlands drainage for any county in the U.S.

that has on-farm wetlands. There were 78.4 million acres of non-Federal wetlands remaining in 1982. However, only 17 million have some probability of being converted to cropland. On about 6 million of these, swampbuster is likely to be effective, but on the remaining 11 million acres, conversion and drainage will not be impeded by swampbuster. Thus Heimlich concludes that swampbuster must be supplemented by other programs and measures if the Nation's on-farm wetlands are to be preserved.

88. Leitch, J.A., and K.L. Grosz. 1988. Wetlands and agriculture in transition: a look at wetlands protection in North Dakota. Pages 95-98 in P.J. Stuber, coordinator. Proceedings of the national symposium on protection of wetlands from agricultural impacts. U.S. Fish and Wildlife Service Biological Report 88(16). Washington, DC.

North Dakota has been a hotbed of opposition to Federal programs to conserve prairie pothole wetlands. The authors looked at the potential impact of swampbuster on farmland drainage of prairie pothole wetlands in North Dakota. They also noted the widespread controversy that the swampbuster provisions of the Food Security Act of 1985 have created in North Dakota. Swampbuster upset North Dakota State legislators and their constituents; in a legislative effort to exempt the State's farmers from the provisions of swampbuster, North Dakota passed a no-net-wetlands-loss farm bill that requires acre-for-acre restoration of drained wetlands. The law becomes effective if the swampbuster sanctions are relaxed for North Dakota.

Historic county average prices make drainage profitable in central North Dakota grain (barley and wheat) cropland. However, Leitch suggests that the net effect of the 1985 Farm Bill will be to lower grain prices so much that drainage will typically be unprofitable unless the farmers who drain receive Federal crop support payments. Hence Leitch concludes that the swampbuster sanctions will provide a strong sanction against on-farm drainage of wetlands as long as agricultural crop prices are low.

89. Leitch, J.A. 1989. Politicoeconomic overview of prairie potholes. Pages 2-14 in A. Van Der Valk, ed. Northern prairie wetlands. Iowa State University Press, Ames.

This is a brief overview of the prairie pothole allocation problem that is enlivened by some specific examples of government mismanagement on the part of the U.S. Fish and Wildlife Service. Prior to 1976, easements purchased by the Service on lands described by the township-range system did not specify the extent or the location of wetlands within blocks of easement purchase lands. Leitch asserts that this caused numerous legal problems and a diminished reputation for the Service among local residents. The prairie pothole allocation problem, like the wetlands allocation issue, is primarily one of allocating a resource that provides high public benefits but low private benefits. Conversion of on-farm prairie pothole wetlands produces croplands, a resource which provides sizeable returns to private ownership. Reconciling the divergence between public and private ownership for the wetland allocation issue is not easy; Leitch, who resides in the prairie pothole region, is particularly adept at focusing on the vacuity of various wetlands preservations efforts that are not sensitive to the regional versus national interest dichotomy. He believes that an approach that

focuses only on the national perspective for the wetlands allocation issue often overlooks the critical nonpecuniary factors underlying wetland drainage in the northern Great Plains of the U.S. Nonpecuniary returns to drainage investment include weed and insect control from eradication of one of the breeding places of these pests. Attitudinal factors (e.g., a good farm is a tidy farm, and a tidy farm has no wetlands) and the collective ethic and aesthetic values of the farmers of the region play an important role in the on-farm conversion of prairie potholes.

90. Leitch, J.A., and B.L. Ekstrom. 1989. Wetland economics and assessment. Garland Publishing, Inc., New York. 194 pp.

This is an up-to-date annotated bibliography of wetlands valuation, assessment, regulatory, and management literature. There are 561 references, with a decided emphasis on post-1974 literature. There are five sections to the bibliography proper, a useful introduction, and author and subject indexes in this compact book. The various sections deal with general topics, assessment, economic valuation, management, regulations (policies and programs), and social values. The economic valuation section is the heart of the book, with 204 citations. The major strengths of the book are the quality of the writing and analysis in the introduction and the large number of literature citations. The introduction is refreshingly forthright and opinionated; Leitch and Eckstrom argue, correctly I believe, that incorrect economic analysis will only impede the wetlands preservationist effort, regardless of the magnitude of the alleged preservation values.

However, the authors could have been a bit more candid by mentioning Gosselink, Odum, and Pope ([9]) (or Pope and Gosselink [8] as well as numerous others) and the ecosystem life support valuation methodology by name. Also, there is a serious problem with dismissing these proconservationist valuations papers as inept economics research. Some of the prodevelopment arguments often made in the natural resource allocation policy arena are also inept as pieces of economic analysis, yet highly persuasive as political rhetoric.

Natural resource economists will have to devise some means of appreciating the multi-faceted needs served by these interdisciplinary rhetorical articles while at the same time drawing attention to the fact the slipshod economic analysis is always insipid for all those who have sufficient training to readily spot the analytic inadequacies. The discussions are terse; brevity is a virtue, particularly in a bibliography published as a journal article, but many of the discussions given here are too brief for a book-length bibliography. It would be very helpful to know which works Leitch and Eckstrom deem to be seminal. This could have been readily accomplished by varying the length and detail of the discussions. Arguably, Hammack and Brown's book (see [10]) on migratory waterfowl and prairie potholes is the best and most important piece of economic analysis on wetlands. Leitch and Eckstrom cite this work, but provide no discussion. The heavy emphasis on brevity does not detract from the overall usefulness of this important work, but it does leave the reader with the impression that the authors are more emotionally detached from the subject than is the case.

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Aaron J. Douglas

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U.S. Fish and Wildlife Service
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Fort Collins, CO 80526-2899

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This bibliography focuses on valuation problems that arise from wetlands allocations issues and conflicts. Thus it deals, almost exclusively, with research and policy analysis that focuses on wetlands economics. There is a wide variety of both analytic approaches and policy perspectives in the wetlands economics literature. Some useful themes emerge from the medley of issues and perspectives, however, and summarizing the research results and policy discussions so that the thematic unity of the subject is highlighted is one of the principal aims of this bibliography. A brief discussion of natural resource economics precedes the bibliography in an effort to ease the burden of recognizing the unity of approaches and concepts employed in the assembled references.

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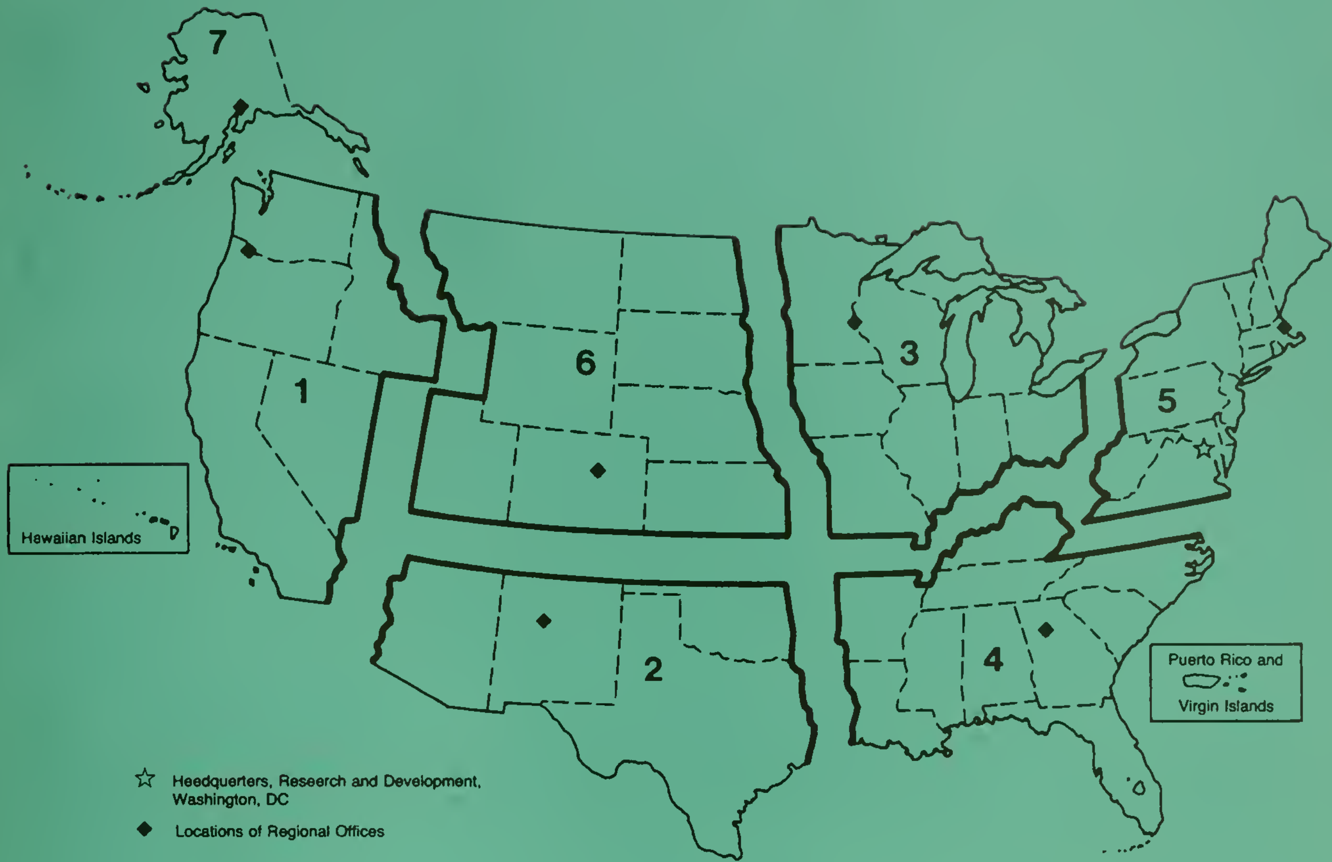

REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

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